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OLIN INDUSTRIES REPORT

on

\*DEVELOPMENT OF LEGLANCHE  
BATTERIES WITH IMPROVED STORAGEABILITY\*

to

Squier Signal Corps Laboratories

Contract No. DA-36-039-SC-5489

Final Report

May 1, 1951 to August 31, 1953

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PURPOSE

Contract DA-36-039-SC-5489 between Olin Industries, Inc. and Squier Signal Corps laboratories provides that research investigations shall be conducted leading toward the development of dry batteries that will be capable of long storage at elevated temperatures.

More specifically basic studies are to be conducted on the constituent parts of the LeClanche electrochemical system to determine the characteristics that affect shelf life at high temperatures. These studies shall aim toward production of batteries of the LeClanche type that meet these requirements.

(a) They shall retain at least 50% of their initial capacity after the following periods of storage under the conditions indicated:

- (1) 12 months storage at 113°F, 95% R.H.
- (2) 3 months storage at 130°F, 50% R.H.
- (3) 2 weeks storage at 160°F, 50% R.H.

(b) They shall meet the general requirements of specification JAN-B-18.

(c) When they are tested at 160°F as specified in JAN-B-18A, par. B-9a the sealing compound used shall not flow.

(d) Their dimensions shall be such that they can be built into batteries conforming to the standard battery line as proposed by S.C.E.L.

(e) They shall be so designed that their manufacture shall be commercially feasible for large scale production.

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ABSTRACT

This is the final report summarizing the work that has been carried on by Olin Industries, Inc. for Squier Signal Corps Laboratories on investigations leading to the development of LeClanche batteries with improved storageability.

Efforts during the period specified by the contract was directed to the investigation of the:

1. Stability of Manganese Dioxide

Twenty-two types of manganese dioxide of varying crystal structure were stored in battery electrolyte at 113°F, confirming the fact that those materials having an initial structure of epsilon, delta or gamma undergo considerable crystal change when stored in contact with battery electrolyte. Materials having a rho, pyrolusite, gamma B or cryptomelane structure undergo only a slight change in crystal structure under the same conditions.

2. Separator Materials

Forty-three types of separators were tested for a period of twelve months at 113°F. These results show that flours undergo more serious oxidation than most starches. All the starch materials tested to date reduce the voltage of manganese dioxide to about the same level as do corn or potato starch. Generally the reduction of the manganese dioxide (voltage loss) occurs quite rapidly during the first month of storage. Thereafter reduction is relatively light. This is true for all samples tested. Of all the samples tested, none appear to be any more resistant to oxidation than the corn or potato starch.

Thirty-two of the most promising separator materials were tested at 160°F for six weeks, indicating that most conventional starch materials lose their gel structure when in contact with battery electrolyte at this elevated temperature within a period of two to four weeks.

Results have been obtained which show that the majority of the voltage reduction of manganese dioxide when in contact with a starch separator is due to some soluble material present in the initial starch or formed by the acid action of the electrolyte on the starch. Studies have also shown the amount of voltage reduction decreases as the pH of the paste electrolyte is increased until the pH is reached at which diamine forms. After this point, voltage reduction is essentially constant.

3. Polarisation

Polarization apparatus was designed to test the passive tendencies of the anode without removing it from the corrosive media.

Considerable work was carried out on anodic and cathodic polarization.

Several types of inhibitors were studied as to their effect on the polarization of zinc. The best inhibitors were found to be Antaron R-155, ammonium dichromate, ammonium chromate, sodium dichromate and a mixture of sodium dichromate and Antaron R-155. However, the chromate film gives high anodic polarization. A desirable inhibitor for a dry cell should cause zinc to exhibit high cathodic polarization and moderate anodic polarization. Amalgamation of zinc does not give satisfactory inhibition, as the amalgamation process tends only to equalize the voltage of anodic and cathodic areas on the zinc surface. It does not set up a corrosion barrier in terms of polarization. This means that any potential difference on the zinc surface will cause serious corrosion. With amalgamated zinc especially, the corrosion process does not appear to be a direct liberation of hydrogen but rather the discharge of free zinc which in turn reacts with the electrolyte to form hydrogen.

Continued polarization studies show that the chromate ion is the best inhibitor tested to date for cells which are stored at elevated temperatures. Cells have been fabricated and tested which gave very satisfactory service after storage at 113°F, 95% R.H. for one year. Best results were obtained using a chromate inhibitor in the paste and barium chromate as a reservoir for chromate ions in the depolarizer itself.

Weight loss measurements and polarization studies indicate that percentages above 1.0% of chromate is the best concentration for inhibiting zinc, especially at elevated temperatures. These same studies were made with varying degrees of amalgamation of zinc and indications are that this process is not satisfactory for inhibiting zinc at elevated temperatures due to the fact that little or no corrosion barrier is set up.

#### 4. Subseal

Cells using a polyethylene gasket as a substitute for a wax sub-seal, with a heat resistant polystyrene top seal gave better capacities and exhibited considerably less leakage than cells with only a wax subseal and heat resistant polystyrene top seal after storage for two weeks at 160°F.

#### 5. Substitute for Starch-Four Gel Separator

The study of liner materials to replace the conventional starch separator in cells which must undergo elevated temperature storage, including paper liners coated with polyvinyl alcohol, carboxy methyl cellulose, methyl cellulose, proteins, glutens, and gum type materials. Data available to date, indicates that cells fabricated with methyl cellulose coated paper liners, polyethylene gasket as a sub-seal and heat resistant polystyrene top seal, have met the requirements of 130°F, 50% R.H. and 160°F, 50% R.H. storage capacity.

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**PART I**

**EQUIPMENT - PROCEDURE**

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FACTUAL DATA

Part I - Equipment and Procedure

1. High Temperature Baths and Humidity Ovens

Four water baths were purchased from the Precision Scientific Company of Chicago, Illinois. Three of these were put into operation, and one was kept in reserve in case of mechanical failure in any one of the others. Two baths have a working area of 18" x 12" x 8 $\frac{1}{2}$ " each and the other two have a working area of 36" x 18" x 12" each. They are thermostatically controlled and can be maintained within plus or minus one-half of one degree of the desired setting. Also, they are equipped with a device which, besides maintaining a constant water level, will also provide for water circulation and more constant conditions throughout.

These baths were used to store manganese dioxide samples, and to maintain the correct temperature conditions for corrosion experiments, starch-flour voltage reduction of manganese dioxide, storage of samples used for polarization studies and ion substitution into the structure of a gamma type manganese dioxide.

Two constant humidity ovens were ordered and purchased from the American Instrument Company of Silver Springs, Maryland. One steam humidified cabinet, inside dimensions 24" x 24" x 24" stainless steel interior and lacquered steel exterior for operation on 230 volts, 60 cycles A.C. current, one steam humidified cabinet, inside dimensions 50" x 24" x 24" stainless steel interior with lacquered steel exterior for operation on 230 volts, 60 cycles A.C. current.

Completed cells were stored in these ovens at the conditions and for the times specified by this contract. These are two weeks at 160°F and 50% relative humidity, three months at 130°F and 50% relative humidity and twelve months at 113°F and 95% relative humidity.

2. Polarization Apparatus

The polarization apparatus used in this study is shown in Figure 1. It consists essentially of two units. One unit supplies the polarization current and imposes a desired anode current density on the zinc electrode. The power source is a three volt battery connected in series with a variable resistance box, a milliammeter, and a switch. One lead of this circuit is connected to a carbon rod which serves as a power electrode, the other lead to the zinc anode. This anode has a controlled surface area of 0.785 cm. By means of the resistance box it is possible to vary the current in the circuit which in turn controls the current density of the anode. The current density was regulated to such a value as to compare with existing tests on cells of normal construction

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The second unit of this apparatus consists of a zinc anode and the electrode of a saturated calomel half cell. The measurement obtained is the open circuit voltage of the zinc anode against the calomel reference electrode. The initial closed circuit voltage of this couple is imposed on the anode and the voltage can be read at various intervals of time after the polarization current has been started, and while polarization current density is held constant by means of the variable resistance box. A saturated calomel half cell is electrolytically connected with the corrosion solution by means of modified salt bridge which has a saturated potassium chloride solution in the arm contacting the calomel cell. The other arm of the bridge can be filled with corrosion solution under investigation. The junction of the two liquids occurs around a three-way stopcock shown in Figure 1.

The voltage measurements are made by an electronic voltmeter and a potentiometer which are connected in the circuit with a double throw switch. This makes it possible to read the voltage with either the voltmeter or the potentiometer. The former is used to obtain accurate measurements of the open circuit voltage.

A modification of this apparatus is used to measure anodic and cathodic polarization jointly. In the latter tests, a zinc strip of controlled area (0.785 sq. cm.) is substituted for the carbon power electrode in the power supply. The polarization current is varied and readings are obtained from each electrode.

The construction of the zinc anodes is of particular interest, they consists of a zinc disc one centimeter in diameter which is bonded by means of an inert wax (probably DeKotinsky cement) to a short section of glass tubing of the same external diameter. A wire lead extends down through the glass tube and is soldered to the center of the disc. Both the wire lead and the open end of the glass tube form a vapor tight seal with a rubber stopper.

The rubber stopper which fits a sample bottle contains two other holes which accomodate one leg of the salt bridge and the power electrode (See Figure 1). During storage periods these holes are closed with a short section of solid glass rod. It is to be noted that the zinc electrode can be tested on the polarization apparatus without removing it from the corrosion media. Furthermore because of the construction of the salt bridge the corrosion solution is not contaminated by foreign ions during the polarization measurements.

### 3. Storage Containers for Manganese Dioxide Studies

Different crystal types of manganese dioxide were stored in glass sample bottles in water baths maintained at the temperatures specified by this contract.

### 4. Electron Microscope

The electron microscope was used for the most part in examining the crystallographic changes occurring in the manganese dioxide during storage.

Additional checks were made by X-ray diffraction whenever it seemed necessary.

### 5. Chemical Analysis

Chemical analysis was used to determine the amount of reduction of manganese dioxide caused by separator materials. It is also being used to characterize further new types of manganese dioxide.

#### 6A. Apparatus for Measuring Manganese Dioxide Voltage (Untamped Depolarizer)

The voltage of manganese dioxide samples stored in contact with various separating materials was measured by employing the following techniques:

A hole  $3/32$ " in diameter and  $1/8$ " depth is drilled in the end of a carbon rod and a small quantity of mix is solidly tamped into this cavity. The end of the rod containing this miniature mix slug is then pressed against a flat zinc anode using starch coated flat cell paper as a separator. The voltage of the couple is read on a potentiometer or very high resistance voltmeter. The method had proved reliable and reproducible. It is possible also to read the voltage of the manganese dioxide coupled with a calomel reference electrode instead of a zinc electrode by a slight modification in the procedure.

#### 6B. Apparatus for Measuring Manganese Dioxide Voltages (Tamped)

The voltage of manganese dioxide samples stored as AA cores in contact with various separating materials was measured in the following manner:

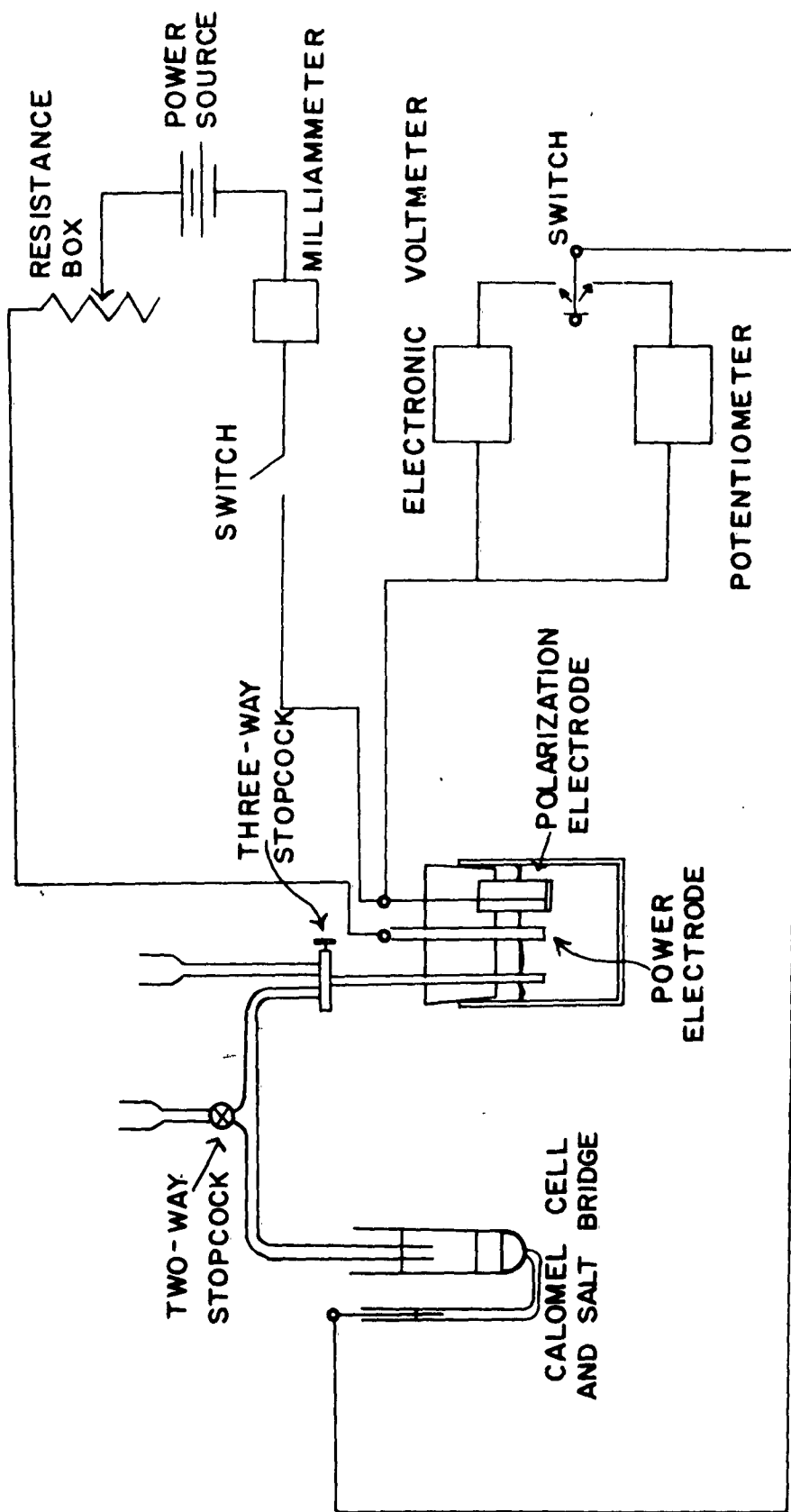
One leg of a modified salt bridge is filled with electrolyte and brought into contact with the separator material which has been stored in a glass jar in contact with an AA core of the manganese dioxide being tested. The second leg of this salt bridge (containing a saturated KCl solution) contacts a calomel half-cell. A lead wire from the calomel cell to the negative terminal of a potentiometer and a lead wire from the carbon rods of the AA core to the positive terminal of the potentiometer completes the circuit. It is then possible to read the voltage of the manganese dioxide coupled with the voltage of the calomel reference electrode. This procedure eliminates problems which arise when a zinc anode is present.

### 7. Machine for Coating Paper

A gum label machine was purchased from New Jersey Machine Corporation of Hoboken New Jersey. This pony gummer was adopted for coating short lengths of paper.

# EQUIPMENT FOR MEASURING ZINC POLARIZATION

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**PART II**

**STABILITY OF**

**MANGANESE DIOXIDE**

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Part II - Stability of Manganese Dioxide

1. Effect of Stability on Various Crystallographic Types of Manganese Dioxide

Under tropical storage conditions, background data indicated that certain types of manganese dioxide, when placed in contact with battery electrolyte, were stable and underwent no crystal phase conversion while other types were unstable. This stability or instability directly influenced capacity on delayed tests, and the problem became even more critical as temperatures rose. This conversion or phase change was not critical in itself, because the new phases, when produced outside the dry cell, performed excellently. However, the new physical shape of the manganese dioxide particles formed in the dry cell was extremely important. This change of shape that took place during conversion caused a loss of contact between the particles of manganese dioxide and carbon black. This loss of contact of course made it impossible for the particles of manganese dioxide to participate in the discharge reaction. First proof of this was obtained by re-working the mix from cells in which conversion had taken place, thus re-establishing contact between manganese dioxide and carbon black so that capacities were as high, if not higher, than the original cells.

With this knowledge, a study was initiated in which twenty-two samples of manganese dioxide from various sources and covering the whole gamut of crystallographic types were analyzed.

This was accomplished by placing the manganese dioxide in normal battery electrolyte (24%  $\text{NH}_4\text{Cl}$ , 22.5%  $\text{ZnCl}_2$ , 53.5%  $\text{H}_2\text{O}$  composition by weight) for storage in such a manner as to approximate conventional battery conditions. Each sample of manganese dioxide was stored as a mix consisting of seven parts ore to one part Shawinigan black in contact with battery electrolyte in sealed glass jars. The samples in these jars were then stored in water baths at temperatures of 113°F., 130°F., and 160°F. Samples at 130°F. and 160°F. were later eliminated due to malfunction of the water baths; however, limited results were obtained which showed that little significant difference occurred at these higher temperatures. It was noted that the crystal structure change occurred more rapidly at 160°F. as would be expected due to increased chemical activity.

Small amounts of each sample were removed at various intervals during the storage period and examined with an electron microscope to determine diffraction patterns and morphological structure. These results are compared to analyses of the initial material to show just changes have occurred.

The results of this work are tabulated in Figure #1 and the condensed results are illustrated in a phase diagram, Figure #2.

The summary of the results are as follows:

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Delta Materials - Highly unstable and tend to change to epsilon and then to alpha or convert directly to alpha.

Epsilon Materials - Highly unstable and tend to convert to alpha.

Alpha Materials - Extremely stable.

Rho Materials - Extremely stable.

Beta Materials - Extremely stable.

Gamma A Materials - Tend to convert to alpha. The alpha product, however, is different in appearance than that formed by delta or epsilon conversion. It is hairlike while the latter is bar or burrlike.

Gamma B Materials - If pure phase, appear extremely stable; however, if a Gamma A phase or alpha is present, the stability is lost.

Some gamma materials appear to convert quite rapidly while others do not show a conversion tendency. This can be correlated with the difference in diffraction patterns of various gamma material. For simplicity, the gamma classification has been broken down to include a gamma A and a gamma B sub-division. These sub-divisions are arbitrary and are based upon the relative intensities of the  $1.38 \text{ \AA}^\circ$  and  $1.41 \text{ \AA}^\circ$  lines of the conventional gamma diffraction pattern. Gamma A material is defined by a diffraction pattern containing the  $2.4 \text{ \AA}^\circ$ ,  $2.1 \text{ \AA}^\circ$ ,  $1.62 \text{ \AA}^\circ$  and  $1.41 \text{ \AA}^\circ$  lines, while gamma B is defined by a diffraction pattern containing the  $2.4 \text{ \AA}^\circ$ ,  $2.1 \text{ \AA}^\circ$ ,  $1.62 \text{ \AA}^\circ$  and  $1.38 \text{ \AA}^\circ$  lines. It is possible and quite common to have a poly-phase gamma material wherein the material assumes the stable characteristics of gamma A.

Of some note is the fact that the major structural change of samples tested took place during the first two months of storage. This answers in part the question of poor delayed performance of many materials when tested at three months time along with the effect of pH change, starch reduction and breakdown of cell efficiency.

Capacity results have indicated that rho and beta phase material, although extremely stable, are far from outstanding performance-wise. Whereas alpha and pure phase gamma B not only are stable but also excellent in performance.

To illustrate further the phase changes of an unstable manganese dioxide, work was done using an ore of delta structure (light hydrate). When stored in battery electrolyte for extended periods, light hydrate converts from an apparently unstable delta pattern, through an epsilon stage to an apparently stable cryptomelane phase. With this in mind, experiments have been carried out in which light hydrate was converted to cryptomelane (alpha) before being assembled into batteries. These experiments consisted of leaching light hydrate in different solutions at a constant temperature of  $90^\circ\text{C}$  for seventy-

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two hours. The solutions tested were 20%  $ZnCl_2$ , 20%  $NH_4Cl$ , 20%  $KCl$  and  $H_2O$ . In all cases, a pH level between 3.5 and 4.0 was maintained by the addition of dilute  $HCl$ . Samples of the product were removed at intervals of twenty-four hours to determine the rate at which conversion was taking place. After seventy-two hours at  $90^\circ C$  the solutions were cooled, filtered, washed and then dried in a forced draft oven for twenty-four hours at  $90^\circ C$ .

Besides taking electron diffraction patterns and micrographs of the samples, a chemical analysis was run on the final product. Results of this experiment are given in Figure #3. Except for one case, the final products of leaching gave cryptomelane diffraction patterns. This one exception being  $KCl$  solution where conversion was not completed in seventy-two hours.

The chemical analysis shows that the  $ZnCl_2$  cryptomelane has a density much above that of the others and a formula more close to  $MnO_2$  ( $MnO_{1.96}$ ). These factors tend to prove that the  $ZnCl_2$  cryptomelane is the best of the materials for good storage characteristics. These results are substantiated by capacity results in Figure #4.

2. A Study of the Effects of Introducing Various Ions into the Structure of an Essentially Gamma Type Manganese Dioxide

A study was initiated to determine the effect on the crystal structure of a gamma type manganese dioxide by the introduction of various ions into its structure. Electrolytic manganese dioxide Lot #106 from Western Electrochemical Company was chosen as the manganese dioxide due to its structure which was typical for electrolytic ore. The following salts were introduced into the structure of this ore:

Sodium Chloride	Copper Chloride
Sodium Sulfate	Copper Sulfate
Potassium Chloride	Lead Chloride
Potassium Sulfate	Lead Sulfate
*Barium Chloride	Zinc Chloride
*Barium Sulfate	Zinc Sulfate
Calcium Chloride	Magnesium Chloride
Calcium Sulfate	Magnesium Sulfate
Manganese Chloride	Lithium Chloride
Manganese Sulfate	Lithium Sulfate
Ferric Chloride	Ammonium Chloride
Ferric Sulfate	Ammonium Sulfate

In the samples tested, one hundred grams of manganese dioxide plus two hundred grams of distilled water were used and an acid added ( $H_2SO_4$  for sulfate salts and  $HCl$  for chloride salts with content varied from zero to thirty-

\* Barium salts were discarded due to inability to wash the product thoroughly and to achieve consistent capacity results.

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five grams). The weight of salt added was half the molecular weight in grams except in cases where the valence was greater than one, here one-fourth or one-third the molecular weight was used. The amount of salt used was far in excess of that needed to carry out the reaction but it was necessary to use this excess to smother the effect of any other ion present. After the samples were made up, they were stored in a water bath at 90°C. for a period of a week. After storage the converted ores were washed, filtered and dried.

The crystallographic results of this experiment are tabulated in Figure #5.

Curves shown in Figure #6 detail the conversions which take place in the various acid mediums. It must be understood that these curves are based on electron diffraction analysis and therefore are extremely relative. The quantity of any phase present is based on its relative intensity with regard to the other diffraction lines in the pattern. The intensity of each phase is based on a scale from one to ten.

Evaluation of these converted ores was accomplished by the fabricating and testing of AA size cells for capacity results. This size cell was used for the evaluation because of the small amounts of ore available. The tests on which these cells were evaluated were picked to approximate current density drains equivalent for D size cells. The four tests in the series are 25 ohm light industrial and 650 ohm continuous which are low rate discharge tests and 25 ohm heavy industrial and 66.7 ohm continuous which are high rate discharge tests.

Capacity results are given also in Figure #5 but are incomplete due to difficulties in testing and fabricating these cells.

All ores have been fabricated into cells and results are incomplete pending completion of testing.

The following observations in regard to this study are presented:

Ammonium, potassium and lead favor the formation and stabilisation of the alpha phase regardless of acid concentration.

Zinc, calcium\* and copper favor the formation and stabilisation of the rho phase dependent on acid concentration.

Sodium, magnesium, lithium, manganese favor the formation and stabilisation of the beta phase, dependent upon acid concentration.

Probably the most significant change was introduced by the iron salts which increase the gamma component markedly.

\*Exception calcium sulfate

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It can be noted that at the highest acid concentration, no samples remained unconverted. Also at no time was there any indication of reduction to  $Mn_2O_3$  or some lower oxide.

Based on the assumption that gamma and rho are highly distorted or strained phases of beta a very logical progression can be illustrated as in Figure #7.

It is highly possible that the inherent strains or distortion in the original crystal were relieved completely, (formation of beta) or partially (formation of rho) or increased (formation of a stronger gamma phase). However, the part that alpha plays in this progression cannot be determined unless the unique form of alpha created is also a member of this family.

Some last minute work has been attempted in a try at converting pure phase beta material to gamma by the use of  $FeCl_3$  and HCl at elevated temperature. This has met with failure. But this failure in itself may be a further answer in that the extremely stable beta phase may be completely lacking in voids or channels in the crystal structure, which we know are present in other structures. This lack may make it impossible for the ferric ion to get a foothold and cause a reverse condition.

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CONCLUSIONS

1. Delta, epsilon and gamma A types of manganese dioxide are essentially useless as a depolarizer in dry batteries unless converted to a stable phase.
2. Gamma B, alpha, rho and pyrolusite or beta are extremely desirable as depolarizers in a dry battery. However, the latter two are rather poor performers.
3. The major crystallographic change in manganese dioxide, if any, will take place within two months in a battery on shelf.
4. It is not the conversion material itself that is responsible for poor delayed performance, but rather the inability of it to participate in the discharge reaction due to loss of physical contact with the carbon black.
5. Introduction of ions into manganese dioxide plays an important role in its crystallographic make up.
6. In converting manganese dioxide by introducing ions, it is possible to control the end product by selective use of ions and acid concentration. In other words, it is possible to increase or decrease the amount of distortion or strain within a crystal.
7. It is possible that the whole crystallographic manganese dioxide family is based directly on the beta structure.

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TABLES AND CHARTS

PART II

STABILITY OF MANGANESE DIOXIDE

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FIGURE 1

Tabulated Results of Studies of Crystallographic Changes of Manganese Dioxides of Various Crystal Structures in Contact with a Conventional Battery Electrolyte and Stored at 113°F. in Glass Jars.

	Initially	Crystal	Structure	of Samples	
Manganese Dioxide		2 months	6 months	9 months	12 months
Baker's Analytical	Beta	Beta	Beta	Beta	Beta
Burgess Chemical Ore	Rho and Alpha	Rho and Alpha	Rho and Alpha	Rho and Alpha	Rho and Alpha
New Jersey Zinc Ore	Epsilon	Epsilon (Maj.) Alpha (Min.)	Epsilon (Maj.) Alpha (Min.)	Epsilon (Maj.) Alpha (Min.)	Epsilon Par Alpha
Synthetic MnO <sub>2</sub> R.S. Dean	Rho	Rho	Rho	Rho	Rho
Chemical MnO <sub>2</sub> Verona Chemical Co.	Alpha	Alpha	Alpha	Alpha	Alpha
Lavino Type E.C.	Rho (Maj.) Alpha (Trace)	Rho (Maj.) Alpha (Trace)	Rho (Maj.) Alpha (Trace)	Rho (Maj.) Alpha (Trace)	Rho (Maj.) Alpha (Trace)
Caucasian Ore	Beta	Beta	Beta	Beta	Beta
Asbury Chemical Ore	Rho and Alpha	Rho and Alpha	Rho and Alpha	Rho and Alpha	Rho and Alpha
Synthetic MnO <sub>2</sub> Import Chemical Co.	Gamma-A	Alpha (Maj.) Gamma-A (Min.)	Alpha (Maj.) Gamma-A (Min.)	Alpha (Maj.) Gamma-A (Tr.)	Alpha
National Carbon Artificial Ore	Gamma-A	Alpha (Maj.) Gamma-A (Min.)	Alpha (Maj.) Gamma-A (Min.)	Alpha (Maj.) Gamma-A (Min.)	Alpha
Japanese Electro Ore	Gamma-B	Gamma-B	Gamma-B	Gamma-B	Gamma-B Gamma-B (Tr.)

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FIGURE 1 (Cont.)

Manganese Dioxide	Crystal Structure				
	Initially	2 months	6 months	9 months	12 months
French Erogene	Rho and Alpha	Rho and Alpha	Rho and Alpha	Rho and Alpha	Rho and Alpha
Chemical MnO <sub>2</sub> General Dry Battery Co.	Rho and Alpha	Rho and Alpha	Rho and Alpha	Rho and Alpha	Rho and Alpha
African Ore	Rho	Rho	Rho	Rho	Rho
Light Hydrate Import Chemical Co.	Delta	Epsilon(Maj) Alpha (Min)	Epsilon(Maj) Alpha (Min)	Epsilon } par Alpha	Alpha (Maj) Epsilon(Min)
Montana Ore	Epsilon Alpha	Epsilon Alpha	Epsilon Alpha	Epsilon Alpha	Epsilon Alpha
MnO <sub>2</sub> Lot No. 18 Western Electro Chem.	Gamma-A(Maj) Gamma-B(Min)	Alpha	Alpha	Alpha	Alpha
Dellite Lot No. 23 E.J. Lavino Co.	Rho (Maj) Alpha (Min)	Rho (Maj) Alpha (Tr.)	Rho (Maj) Alpha (Tr.)	Rho (Maj) Alpha (Tr.)	Rho (Maj) Alpha(Tr.)
Electrolytic MnO <sub>2</sub> Bright Star Battery Co	Gamma-A(Maj) Gamma-B(Tr.)	Alpha (Maj) Gamma-A(Min)	Alpha (Maj) Gamma-A(Tr.)	Alpha (Maj) Gamma-A (Min)	Alpha
Chemical MnO <sub>2</sub> Continental Chemical Co	Rho	Rho	Rho	Rho	Rho
Costa Rican Ore	Epsilon	Epsilon(Maj) Alpha (Min)	Epsilon } par Alpha	Epsilon } par Alpha	Epsilon } par Alpha
Electrolytic MnO <sub>2</sub> Burgess Battery Co.	Gamma-B	Gamma-B	Gamma-B	Gamma-B	Gamma-B(Maj) Gamma-A(Tr.)

FIGURE 1 (Cont.)

Crystallographic Progression for the Various Crystal Phases of Manganese Dioxide  
When Placed in Contact with Battery Electrolyte

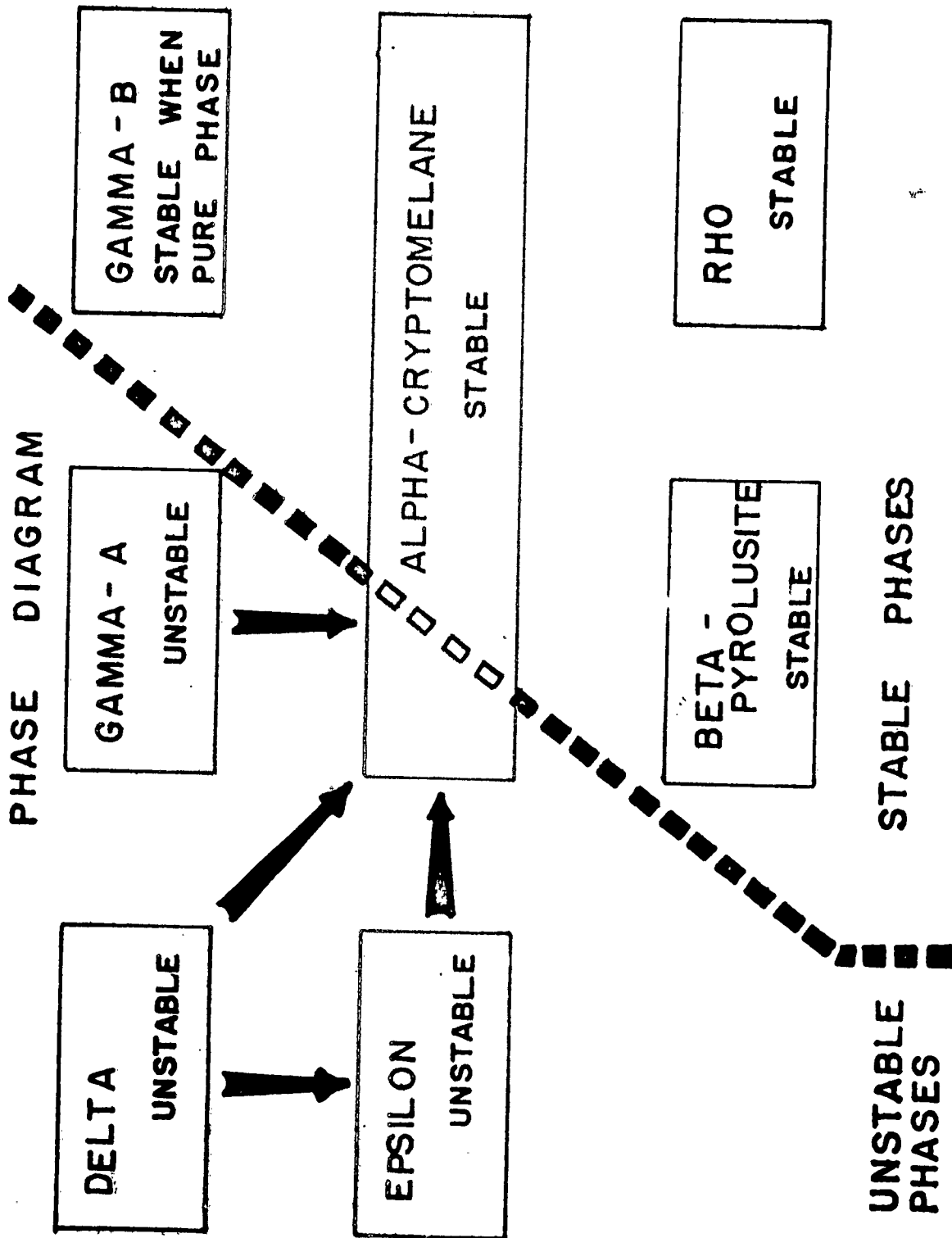


FIGURE 2

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FIGURE 3

Light Hydrate Crystal Structure Change				
Light Hydrate Leached at 90°C. in solutions with Adjusted pH of 3.5 to 4.0. pH adjusted with dilute hydrochloric acid.				
Leaching Solutions				
	20% $\text{NH}_4\text{Cl}$	20% $\text{KCl}$	$\text{H}_2\text{O}$	20% $\text{ZnCl}_2$
Initial Structure	Delta	Delta	Delta	Delta
Structure after 24hrs in solution @ 90°C.	Epsilon (major), some delta	Finely divided epsilon (major), some delta	some delta, some epsilon, fine traces cryptomelane	some delta, finely divided cryptomelane (maj.)
Structure after 48 hr in solution @ 90°C.	Epsilon (major), some cryptomelane	Epsilon (major), some delta, very minor cryptomelane	some epsilon, Cryptomelane (major)	finely divided cryptomelane
Structure after 72 hr in solution @ 90°C.	Cryptomelane (major)	Epsilon (major), some cryptomelane	Cryptomelane (major)	finely divided cryptomelane
Chemical Analysis After 72 Hours At 90°C.				
Density	4.26 gms./ cu.in	9.73 gms/cu.in	5.15 gms/cu.in	10.44 grams per cu. in.
Mn (dry)	55.9 %	53.3%	55.7%	51.1%
$\text{MnO}_2$ (dry)	79.5 %	82.4%	84.2%	78.6%
$\text{H}_2\text{O}$	3.1 %	10.96%	8.36%	4.04%
Formula of resulting ore	$\text{MnO}_{1.88}$	$\text{MnO}_{1.97}$	$\text{MnO}_{1.95}$	$\text{MnO}_{1.96}$
Morphological Characteristics	Bar-like Crystals		Bar-like Crystals	Bar-like Crystals

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FIGURE 4

LeChanche' Type "D" Cells Stored at a Temperature of 160°F.

Book No.	Mix Formulation	Test Results					
		BA 30		BA 8		BA 408/u	
		Initial (days)	2 wks. @ 160°F	Initial (hours)	2 wks. @ 160°F	Initial (hours)	2 wks. @ 160°F
B3327	100% Cryptomelane (Light Hydrate) leached in H <sub>2</sub> O 7.25/1- ore/black	11.1 dys.	1.5 dys.	216 hrs.	56.4 hrs.	21.5 hrs.	4.7 hrs.
B3330	30% Cryptomelane (Light Hydrate leached in H <sub>2</sub> O) 70% African Ore 7.25/1- ore/black	13.4	No Good	173	48.1	17.7	1.5
B3334	100% Cryptomelane (Light Hydrate leached in KCl sol) 7.25/1- ore/black	9.9	7.4	189	29.5	22.0	1.0
B3337	30% Cryptomelane (Light Hydrate leached in KCl sol) 70% African Ore 7.25/1- ore/black	13.5	No Good	190	29.0	22.3	4.0
B3342	30% Cryptomelane (Light Hydrate leached in NH <sub>4</sub> Cl) 70% African Ore 7.25/1- ore/black	12.3	3.1	125	60.9	15.3	7.00
B3346	100% Cryptomelane (Light Hydrate leached in ZnCl <sub>2</sub> ) 7.25/1- ore/black	13.1	4.3	170	78.0	26.0	9.8
B3349	30% Cryptomelane (Light Hydrate leached in ZnCl <sub>2</sub> ) 70% African Ore 7.25/1- ore/black	15.0	6.4	198	79.0	16.6	9.5

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Data on converted 100 gram samples of Western Electro Chemical Ore Lot No. 106 plus 200 grams of water stored in glass jars for one week at 90°C. in contact with various salts and acids as indicated below.

Salt Conversion Data					Crystal Structure				Capacity Data			
Salt Added	Wt. of salt (gms.)	HCl (gms.)	H <sub>2</sub> SO <sub>4</sub> (gms.)	Vol. Visual Increase	Gamma	Alpha	Beta	Rho	25 ohm Lt. (min.)	25 ohm Ind. Hy. (min.)	66.7ohm Cont. (hrs.)	650 ohm Cont. (hrs.)
NaCl	29.72			1 1/2	3	7	T		718	723	40.7	936
NaCl	29.72	10		slight		2	T	8	753	570	29.8	576
NaCl	29.72	35		none		1	6	3	773	576	31.9	525
Na <sub>2</sub> SO <sub>4</sub>	35.51			1 1/2	4	6	T		815	791	36.3	452.4
Na <sub>2</sub> SO <sub>4</sub>	35.51		10	slight		2	T	8	625	634	32.8	522
Na <sub>2</sub> SO <sub>4</sub>	35.51		35	slight			7	3	561	613	29.9	4.4
Na <sub>2</sub> SO <sub>4</sub>	71.02			1 3/4	4	6	T		626	679	38.2	1163
Na <sub>2</sub> SO <sub>4</sub>	71.02		10	slight		2	T	8	632	699	36.1	680
Na <sub>2</sub> SO <sub>4</sub>	71.02		35	slight			5	5	678	654	34.3	513.7
KCl	37.27			doubled		10	T		773	684	37.4	451.8
KCl	37.27	10		1 3/4		7	1	2	851	768	37.3	753.2
KCl	37.27	35		1 1/2		5	1	4	803	717	34.8	685
K <sub>2</sub> SO <sub>4</sub>	43.56			doubled	5	5	T		703	1049	44.7	6d4
K <sub>2</sub> SO <sub>4</sub>	43.56		10	slight	4	6	T		577	699	31.3	484
K <sub>2</sub> SO <sub>4</sub>	43.56		35	slight	3	7	T		669	724	38.9	894
K <sub>2</sub> SO <sub>4</sub>	87.12			doubled	5	5	T		619	626	33.3	482
K <sub>2</sub> SO <sub>4</sub>	87.12		10	1 1/2	4	6	T		694	693	36.1	343
K <sub>2</sub> SO <sub>4</sub>	87.12		35	none	4	6	T		811	746	33.6	483
CaCl <sub>2</sub>	28.85			1 1/2	5	5	T		603	580	44.1	913
CaCl <sub>2</sub>	28.85	10		1 1/4		2	1	7	782	711	35.4	805
CaCl <sub>2</sub>	28.85	35		slight		1	4	5	757	676	35.6	777
Western Electro Lot No. 106-				Control	5	5	T		912	807	38.8	449

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Salt Conversion Data					Crystal Structure				Capacity Data			
Salt Added	Wt. of salt (gms.)	HCl gms.	H <sub>2</sub> SO <sub>4</sub> gms.	Vol. Visual Increase	Gamma	Alpha	Beta	Rho	25 ohm Lt. Ind. (min.)	25 ohm Py. Ind. (min.)	66.7ohm Cont. (hrs.)	650 ohm Cont. (hrs.)
CaCl <sub>2</sub>	57.70			1 1/2	5	5	T		707	604	30.6	372
CaCl <sub>2</sub>	57.70	10		1 1/2		2	1	7	579	502	24.4	546
CaCl <sub>2</sub>	57.70	35		1 1/2		1	3	6	687	564	31.1	517
MnCl <sub>2</sub>	31.46			slight		7	T	1	757	689	50.3	
MnCl <sub>2</sub>	31.46	10		1 3/4		2	1	T	736	617	31.3	474
MnCl <sub>2</sub>	31.46	35		1 1/4			10		817	562	30.9	917
MnCl <sub>2</sub>	62.92			1 1/2		9	T	T	750	671	38.5	955
MnCl <sub>2</sub>	62.92	10		1 1/2		2	1	7	752	567	41.4	549
MnCl <sub>2</sub>	62.92	35		1 3/4			10		687	459	28.2	
MnSO <sub>4</sub>	75.50			1 1/2	1	9	T		724	610	53.4	
MnSO <sub>4</sub>	75.50		10	slight			10	T	74	590	63.3	1035
MnSO <sub>4</sub>	75.50		35	1 1/4					779	700	58.5	909
CuCl <sub>2</sub>	33.6			slight	5	5	T		192	500	44.4	412
CuCl <sub>2</sub>	33.6	10		slight	5	5	T		357	144	42.7	391
CuCl <sub>2</sub>	33.6	35		1 1/2		1	T	9	852	825	40.1	
CuCl <sub>2</sub>	67.2			slight	5	5	T		279	612	61.2	428
CuCl <sub>2</sub>	67.2	10		1 1/4		3	T	T	640	901	50.3	720
CuCl <sub>2</sub>	67.2	35		1 1/2			1	9	927	774	66.2	
CuSO <sub>4</sub>	79.8			slight	5	5	T		153	416	27.8	187
CuSO <sub>4</sub>	79.8		10	slight		2	T	8	912	552	37.4	
CuSO <sub>4</sub>	79.8		35	1 1/4			T	10	892	713	52.4	
FeCl <sub>3</sub>	27.0			1 1/2	6	4	T		595	775	37.2	
FeCl <sub>3</sub>	27.0	10		no change	7	3	T		720	781	36.4	
FeCl <sub>3</sub>	27.0	35		no change	9	1	T		665	835	41.7	
Control - Western Electro Lot No. 106					5	5	T		912	607	30.0	449

Salt Conversion Data					Crystal Structure				Capacity Data			
Salt Added	Wt. of salt (gms.)	HCl gms.	H <sub>2</sub> SO <sub>4</sub> gms.	Vol. Visual Increase	Gamma	Alpha	Beta	Rho	25 ohm Lt. (min.)	25 ohm Ind. Hy. (min.)	66.7 ohm Cont. (hrs.)	650 ohm Cont. (hrs.)
FeCl <sub>3</sub>	81.1			no change	7	3	T		846	717	36.6	766
FeCl <sub>3</sub>	81.1	10		no change	8	2	T		798	730	55.6	16
FeCl <sub>3</sub>	81.1	35		no change	9	1	T		759	777	50.3	
Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	66.7			no change	6	4	T		645	601	30.2	
Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	66.7		10	no change	6	4	T		747	690	48.2	17
Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	66.7		35	no change	6	4	T		688	747	48.5	
Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	100.0			1 1/2	6	4	T		856	749	37.0	942
Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	100.0		10	doubled	6	4	T		887	727	36.9	18
Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	100.0		35	1 1/2	7	3	T		876	773	34.4	
PbCl <sub>2</sub>	69.5			no change	5	5	T					
PbCl <sub>2</sub>	69.5	10		no change	5	5	T					19
PbCl <sub>2</sub>	69.5	35		Doubled		10	T					
PbCl <sub>2</sub>	139.1			1 1/2	5	5	T					
PbCl <sub>2</sub>	139.1	10		1 1/2	5	5	T					
PbCl <sub>2</sub>	139.1	35		doubled		10	T					20
PbSO <sub>4</sub>	151.6			3 1/4	2	7	T	1				
PbSO <sub>4</sub>	151.6		10	3 1/2		9	T	1				
PbSO <sub>4</sub>	151.6		35	doubled		7	T	3				21
ZnCl <sub>2</sub>	34.1			1 1/2	5	5	T					
ZnCl <sub>2</sub>	34.1	10		1 1/4	1	4	T	5		787	60.9	
ZnCl <sub>2</sub>	34.1	35		no change	1	4	T	5		988	61.6	22
ZnCl <sub>2</sub>	68.1			1 1/4	5	5	T			821	53.4	
ZnCl <sub>2</sub>	68.1			1 1/4	1	4	T	5		700	47.4	
ZnCl <sub>2</sub>	68.1	10		1 1/4	1	4	T	5		724	52.4	23
ZnCl <sub>2</sub>	68.1	35		1 1/4	1	4	T	5		768	55.0	
Control - Western Electro Lot No. 106					5	5	T		912	807	38.8	449

FIGURE 5. (Cont.)

Salt Conversion Data					Crystal Structure				Capacity Data				
Salt Added	Wt. of salt (gms.)	HCl gms.	H <sub>2</sub> SO <sub>4</sub> gms.	Vol. Visual Increase	Gamma	Alpha	Beta	Rho	25 ohm Lt. Ind. (min.)	25 ohm Hy. Ind. (min.)	66.7ohm Cont. (hrs.)	650 ohm Cont. (hrs.)	No
ZnSO <sub>4</sub>	80.7			1½	5	5	T			776	43.2		
ZnSO <sub>4</sub>	80.7		10	1½		2	T	8		745	52.2		24
ZnSO <sub>4</sub>	80.7		35	1½			4	6		711	47.2		
CaSO <sub>4</sub>	86.09			4½	4	6	T			460	17.6		
CaSO <sub>4</sub>	86.09		10	4½			1	9		355	26.7		25
CaSO <sub>4</sub>	86.09		35	5			10	T		396	21.2		
(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	33.03			2¼	2	8	T			809	47.0		
(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	33.03		10	3	1	9	T			747	48.3		26
(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	33.03		35	3½		9	1	T			52.6		
(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	66.07			2½	1	9	T				48.7		
(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	66.07		10	3	T	10	T			739	44.8		27
(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	66.07		35	3		10	T			713	40.9		
NH <sub>4</sub> Cl	26.75			2¼	1	9	T			728	47.7		
NH <sub>4</sub> Cl	26.75	10		3½		6	T	4		713	33.5		28
NH <sub>4</sub> Cl	26.75	35		4		4	3	3		660	36.4		
Li <sub>2</sub> SO <sub>4</sub>	31.99			2¾	1	9	T			776	44.9		
Li <sub>2</sub> SO <sub>4</sub>	31.99		10	3		1	6	3		725	56.2		29
Li <sub>2</sub> SO <sub>4</sub>	31.99		35	2			10	T		830	44.9		
Li <sub>2</sub> SO <sub>4</sub>	63.98			2½	1	9	T				64.2		
Li <sub>2</sub> SO <sub>4</sub>	63.98		10	3		T	9	1		777	43.9		30
Li <sub>2</sub> SO <sub>4</sub>	63.98		35	3¼			10			1168	56.0		
LiCl	21.2			2½		9	T	1		724	54.8		
LiCl	21.2	10		2½		2	T	8		1408	52.4		31
LiCl	21.2	35		2			8	2		858	50.4		
Control - Western Electro Lot No. 106					5	5	T		912	807	38.8	449	

FIGURE 5-(Cont.)

Salt Conversion Data					Crystal Structure				Capacity Data			
Salt Added	Wt. of salt (gms.)	HCl gms.	H <sub>2</sub> SO <sub>4</sub> gms.	Vol. Visual Increase	Gamma	Alpha	Beta	Rho	25 ohm Lt. Ind. (min.)	25 ohm Hy. Ind. (min.)	Cell Size Cont. (hrs.)	"AA" Cont. (hrs.)
MgSO <sub>4</sub>	60.2			1½	5	5	T			750	66.7ohm	650ohm
MgSO <sub>4</sub>	60.2		10	3			10	T		677	57.2	
MgSO <sub>4</sub>	60.2		35	3			10			1124	53.8	
MgCl <sub>2</sub>	50.8			1½	5	5	T			721	53.8	
MgCl <sub>2</sub>	50.8	10		3½		3	1	6		818	43.4	
MgCl <sub>2</sub>	50.8	35		2		T	7	3		949	47.6	
MgCl <sub>2</sub>	101.6			2	5	5	T		496	725	43.2	
MgCl <sub>2</sub>	101.6	10		3		2	1	7		834	45.2	
MgCl <sub>2</sub>	101.6	35		2½		T	9	1		754	50.9	
Control- Western Electro Ore No. 106					5	5	T		912	807	38.8	449

FIGURE 5 (Cont.)

End of Data on the Introducing of Various Ions into the Crystal Structure of a Typical Gamma Manganese Dioxide (Western Electro Chemical Ore Lot No. 106). Stored for One Week at 90 C. in contact with various salts and acids.

\*\*\*\*\* Blank spaces in this data are due to incomplete returns of capacity results.

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FIGURE 6

Curves Based on Crystallographic Data on the Effect  
of Introducing Various Ions into the Crystal Structure  
of a Gamma Type Manganese Dioxide.

Crystal Structure  
(relative amounts of phases present based on electron diffraction)

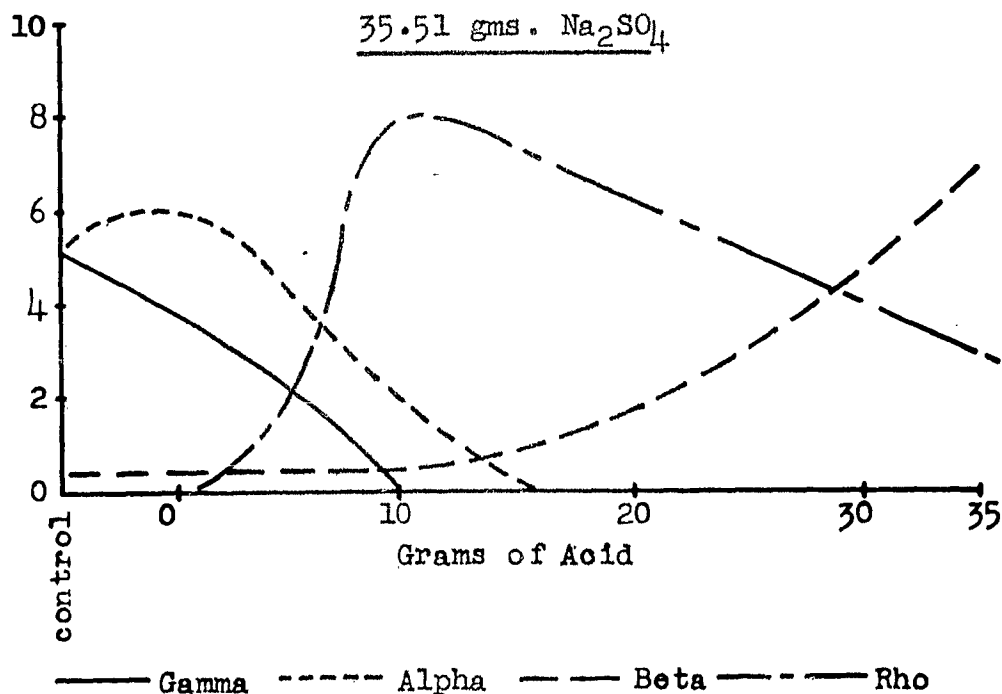
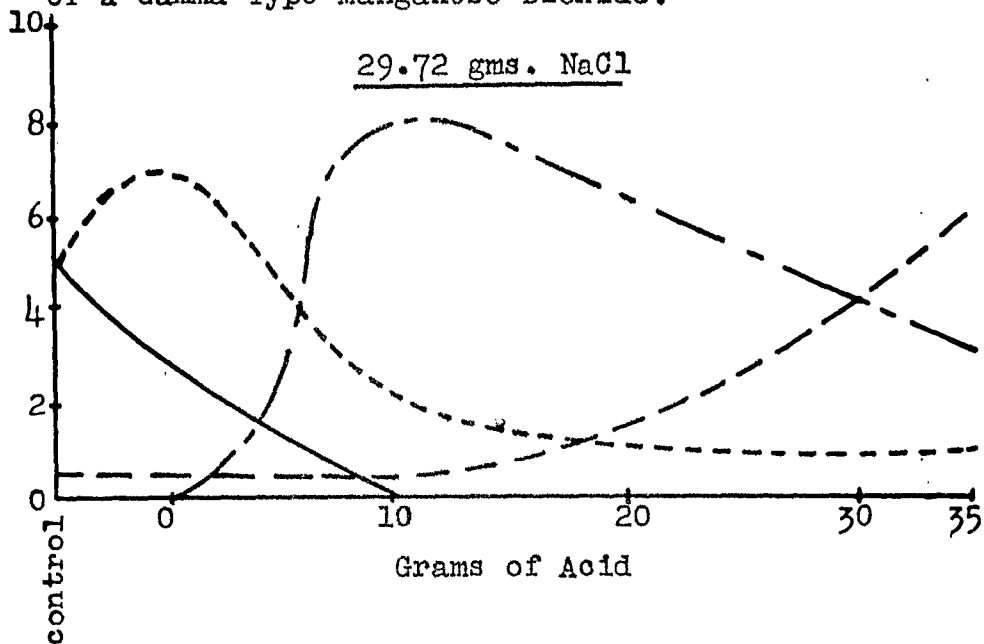
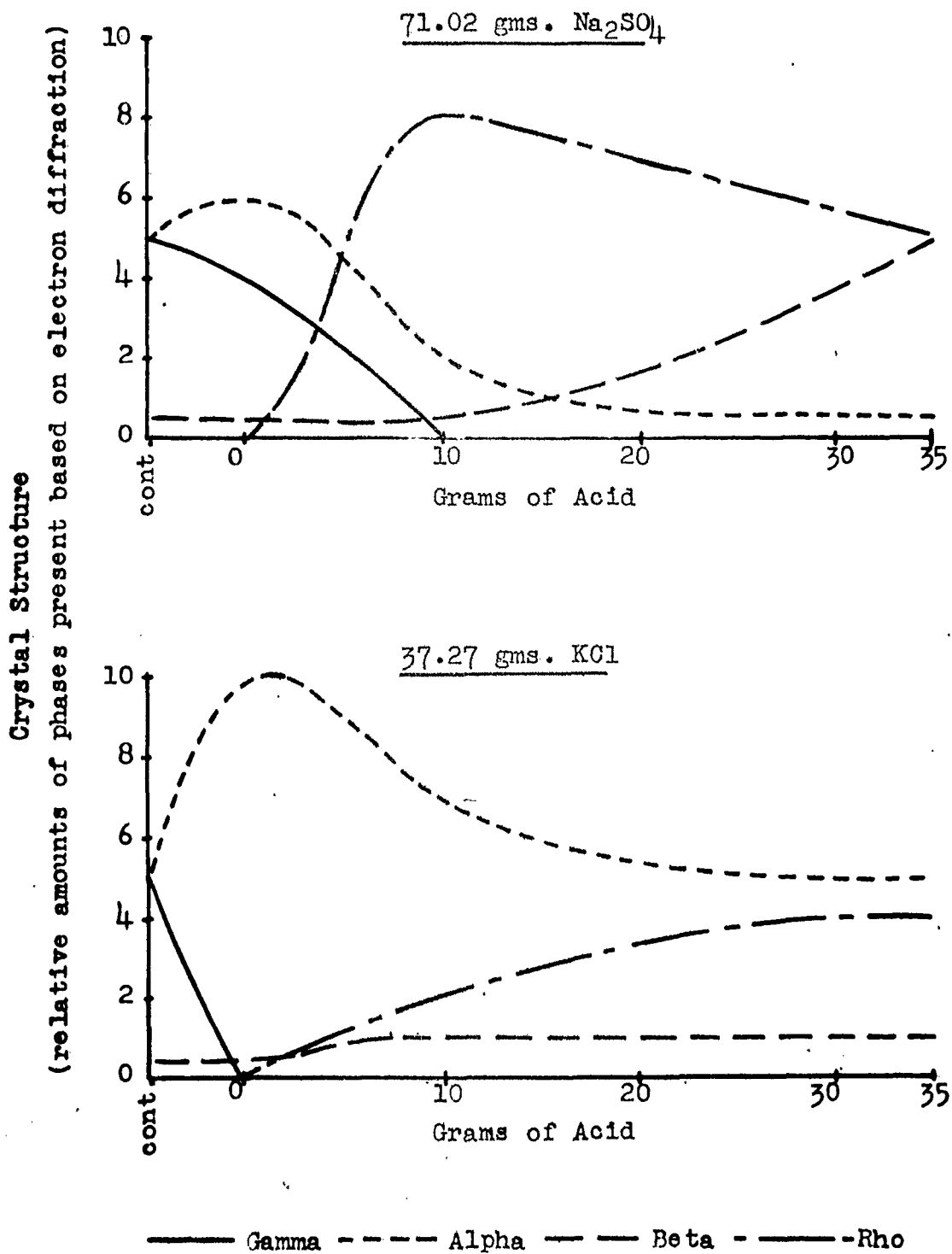


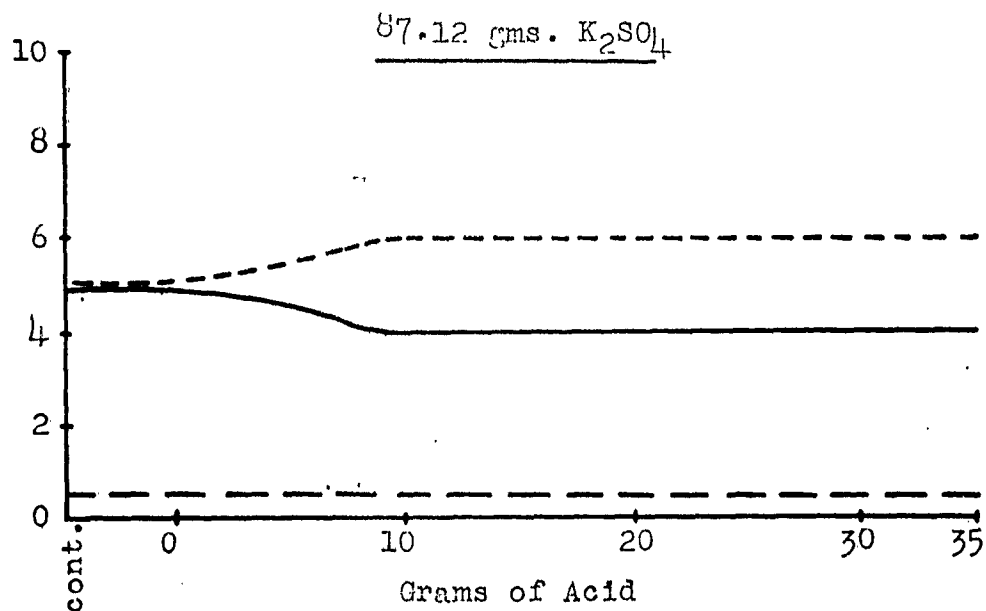
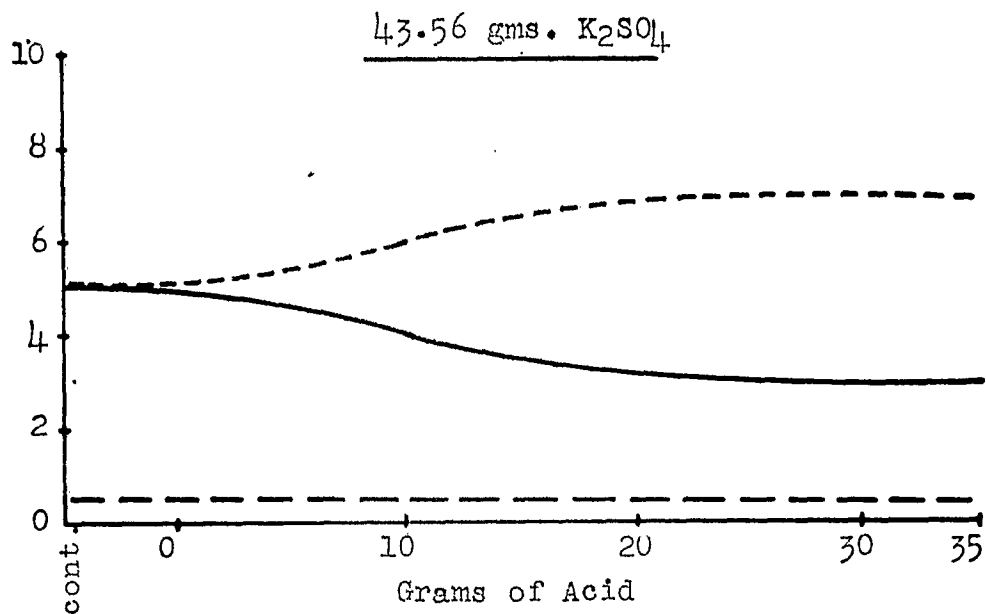
FIGURE 6 (Cont.)



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FIGURE 6.(Cont.)

Crystal Structure  
(relative amounts of phases present based on electron diffraction)

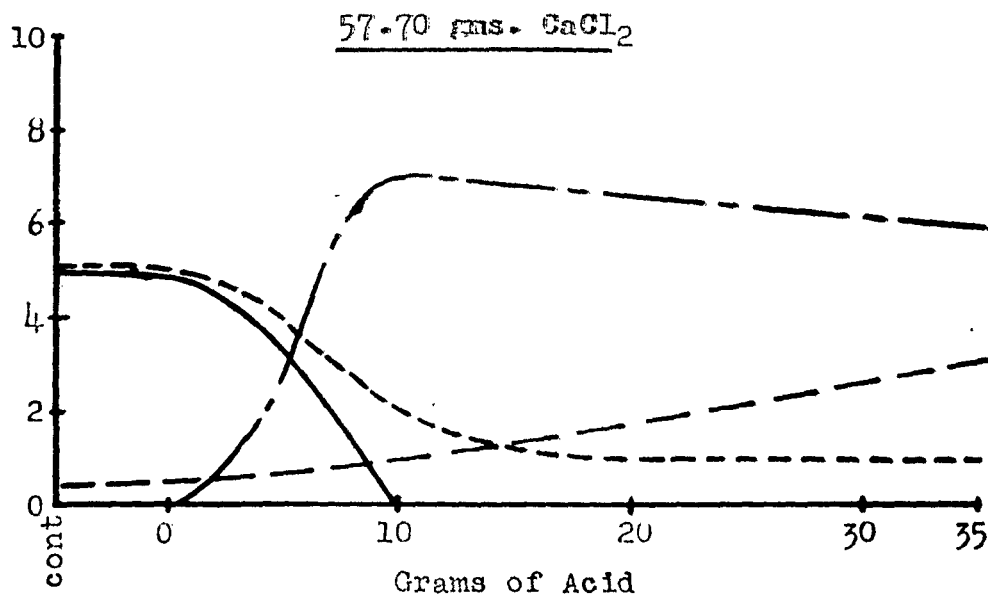
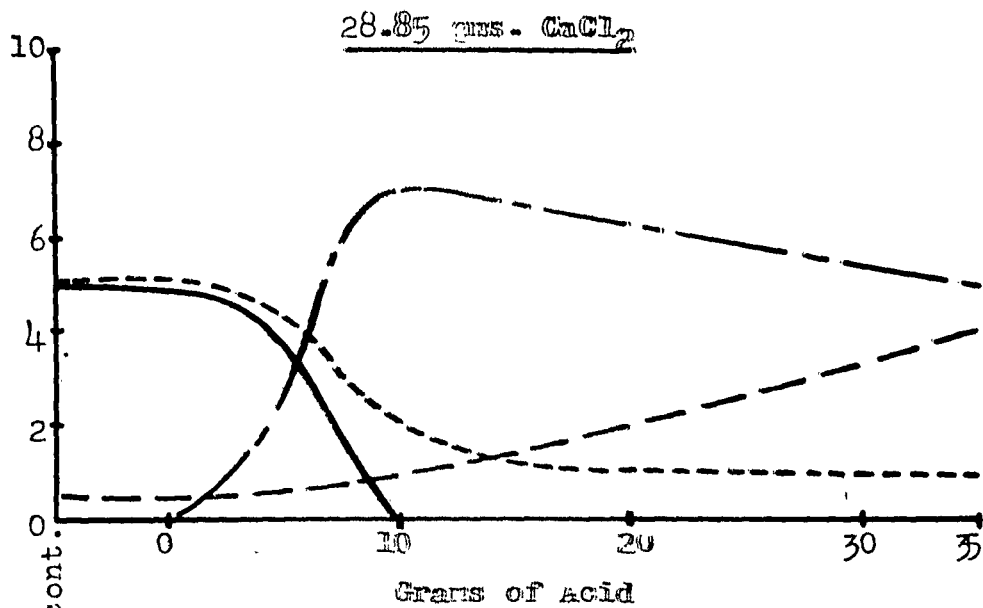


—— Gamma ——— Alpha ——— Beta ——— Rho

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FIGURE 6 (Cont.)

Crystal Structure  
(relative amounts of phases present based on electron diffraction)



— Gamma — Alpha — Beta — Rho

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FIGURE 6 (Cont.)

Crystal Structure  
(relative amounts of phases present based on electron diffraction)

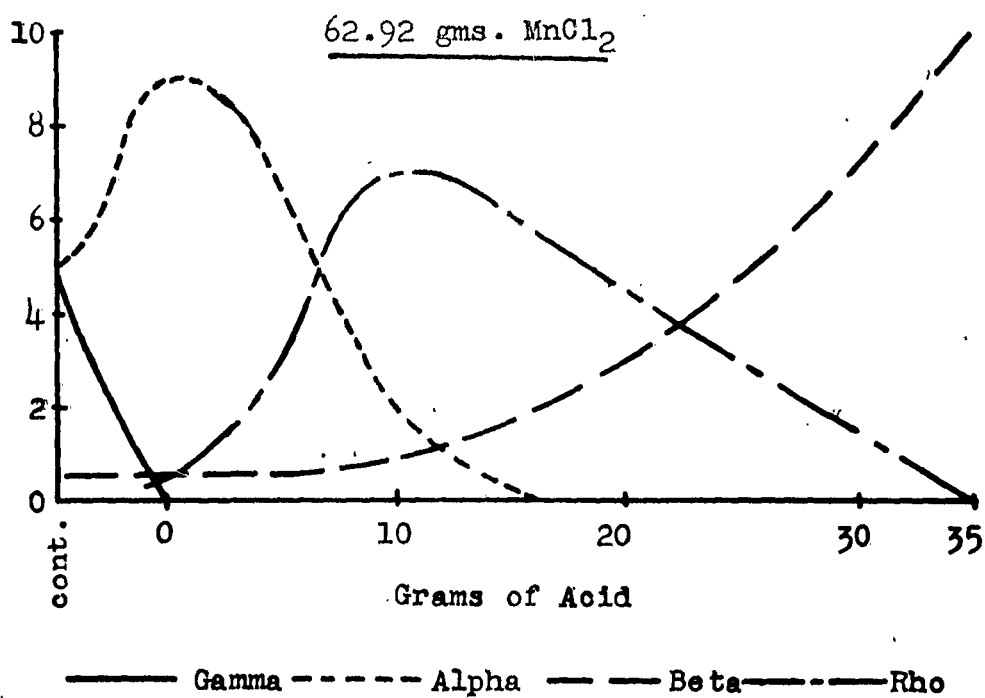
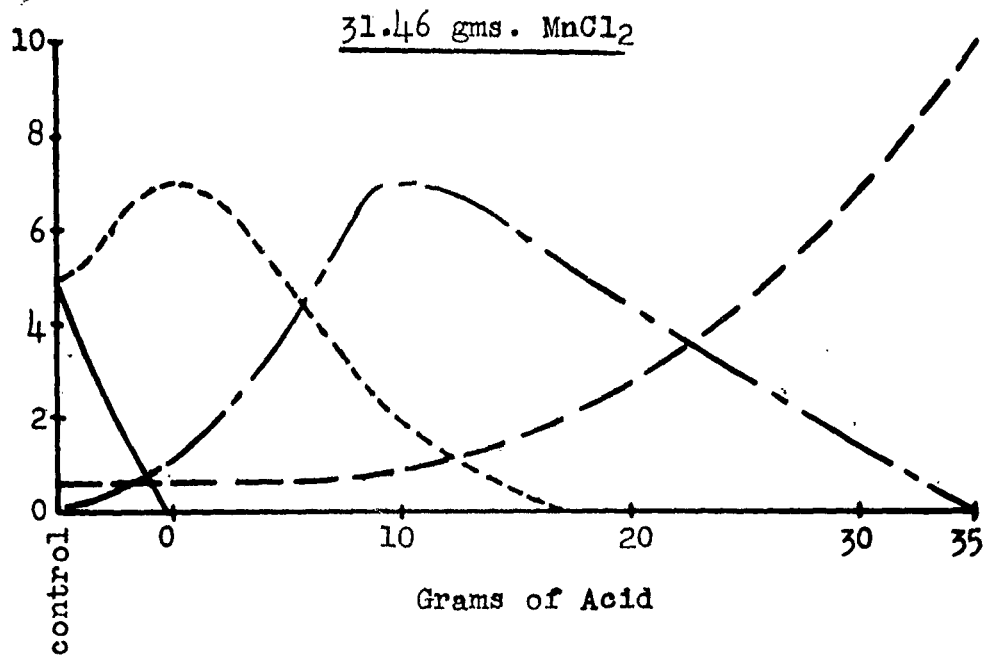


FIGURE 6 (Cont.)

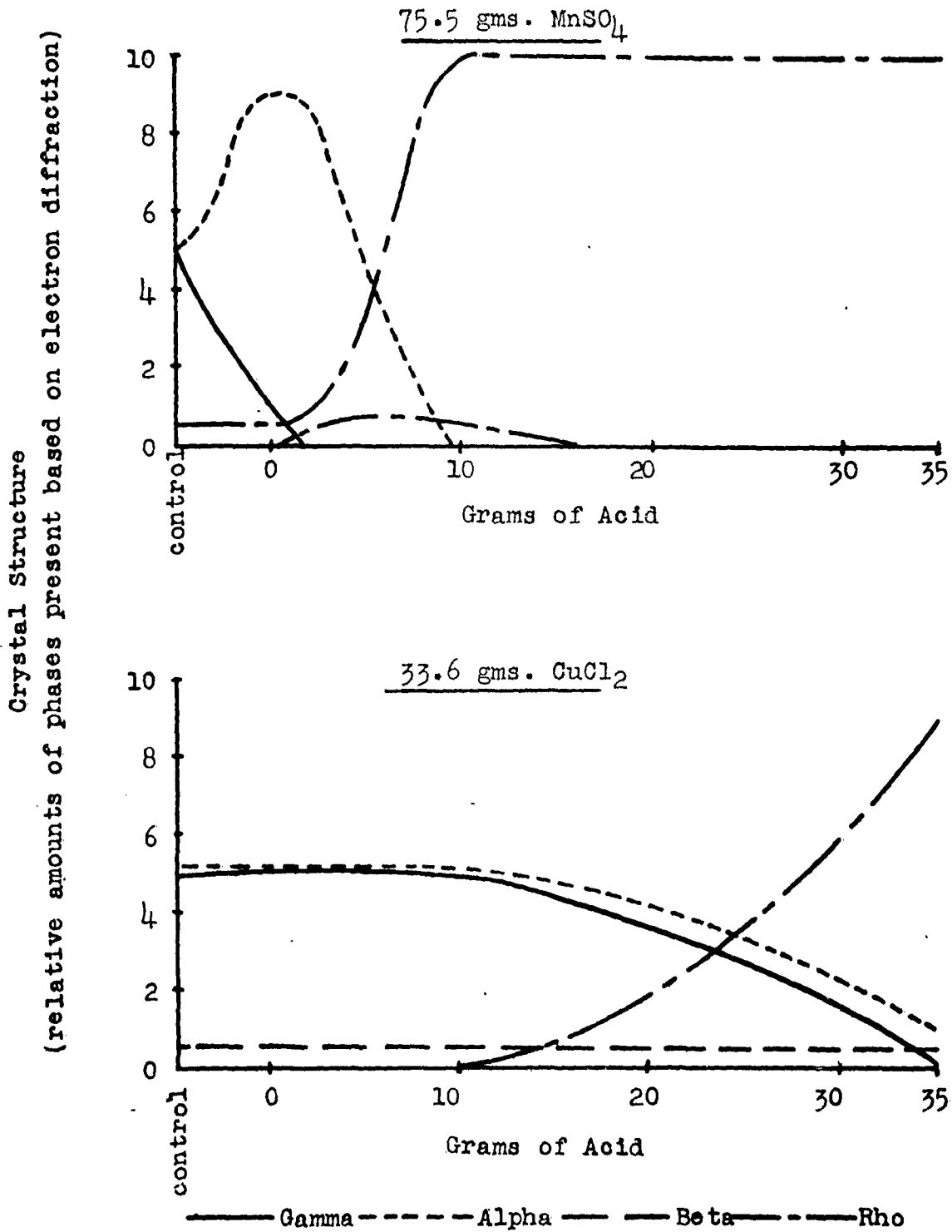


FIGURE 6 (Cont.)

Crystal Structure  
(relative amounts of phases present based on electron diffraction)

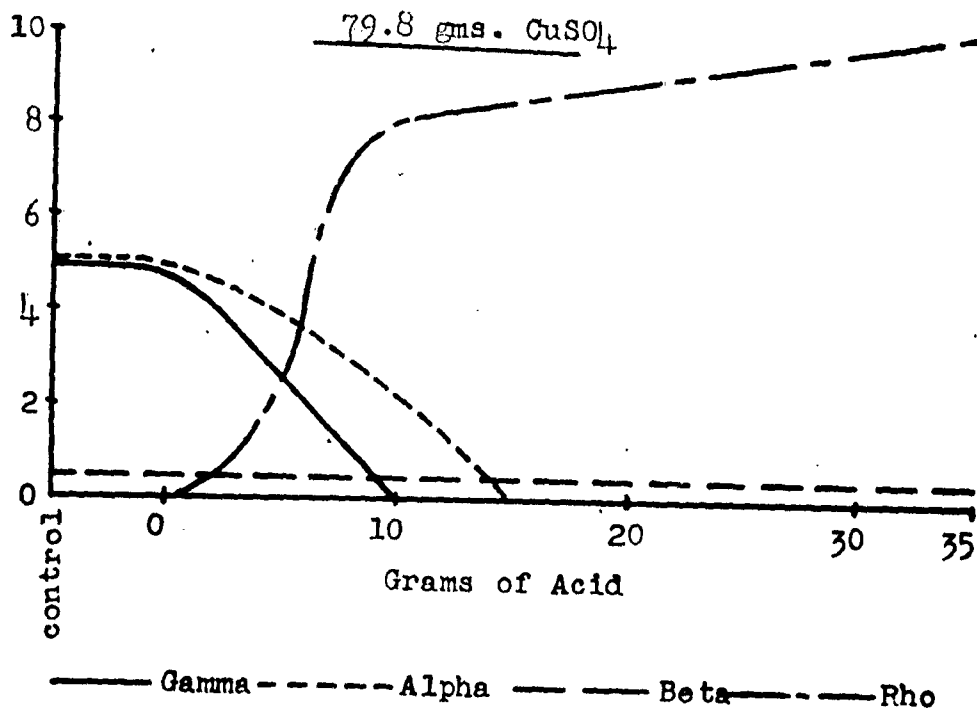
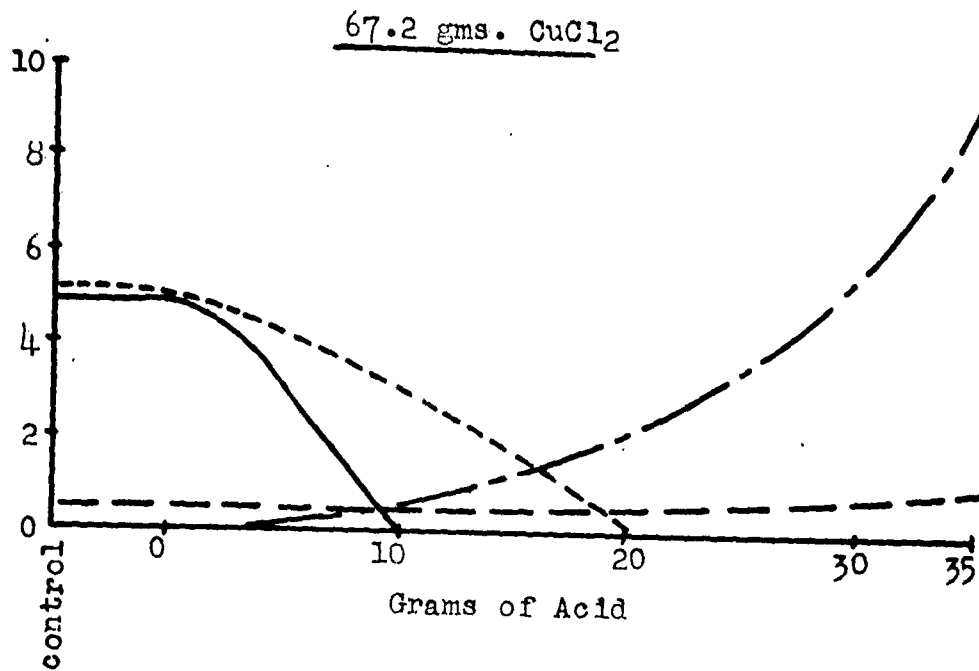


FIGURE 6 (Cont.)

Crystal Structure  
(relative amounts of phases present based on electron diffraction)

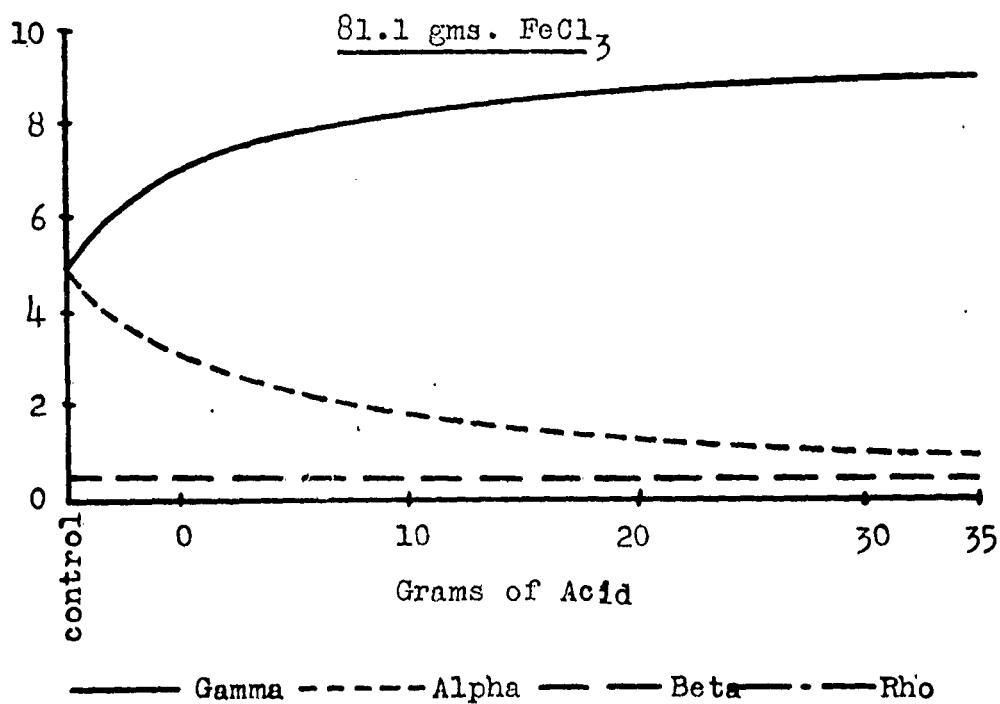
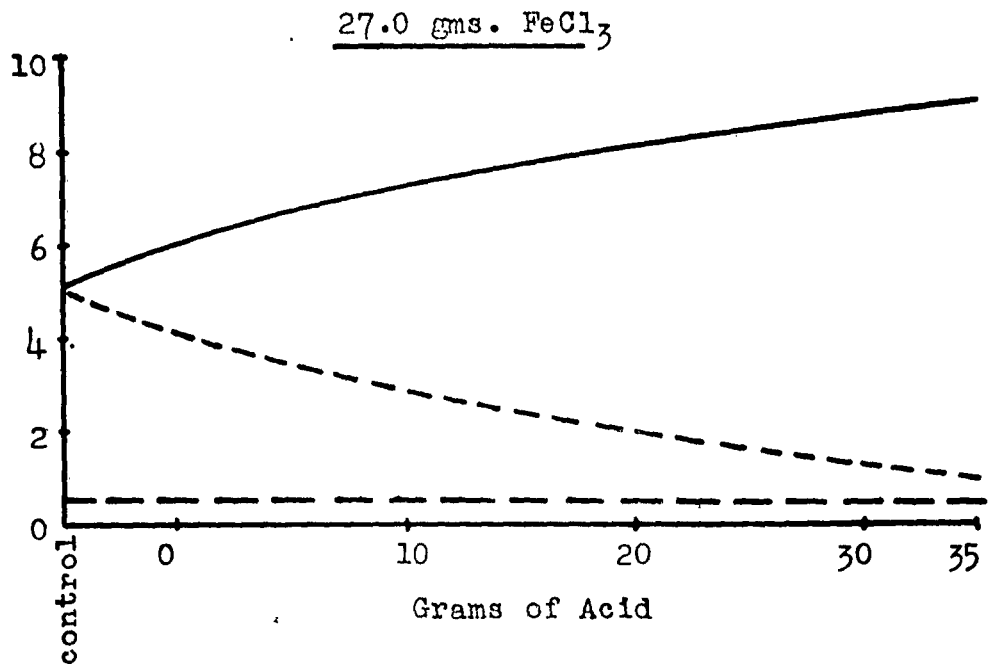


FIGURE 6 (Cont.)

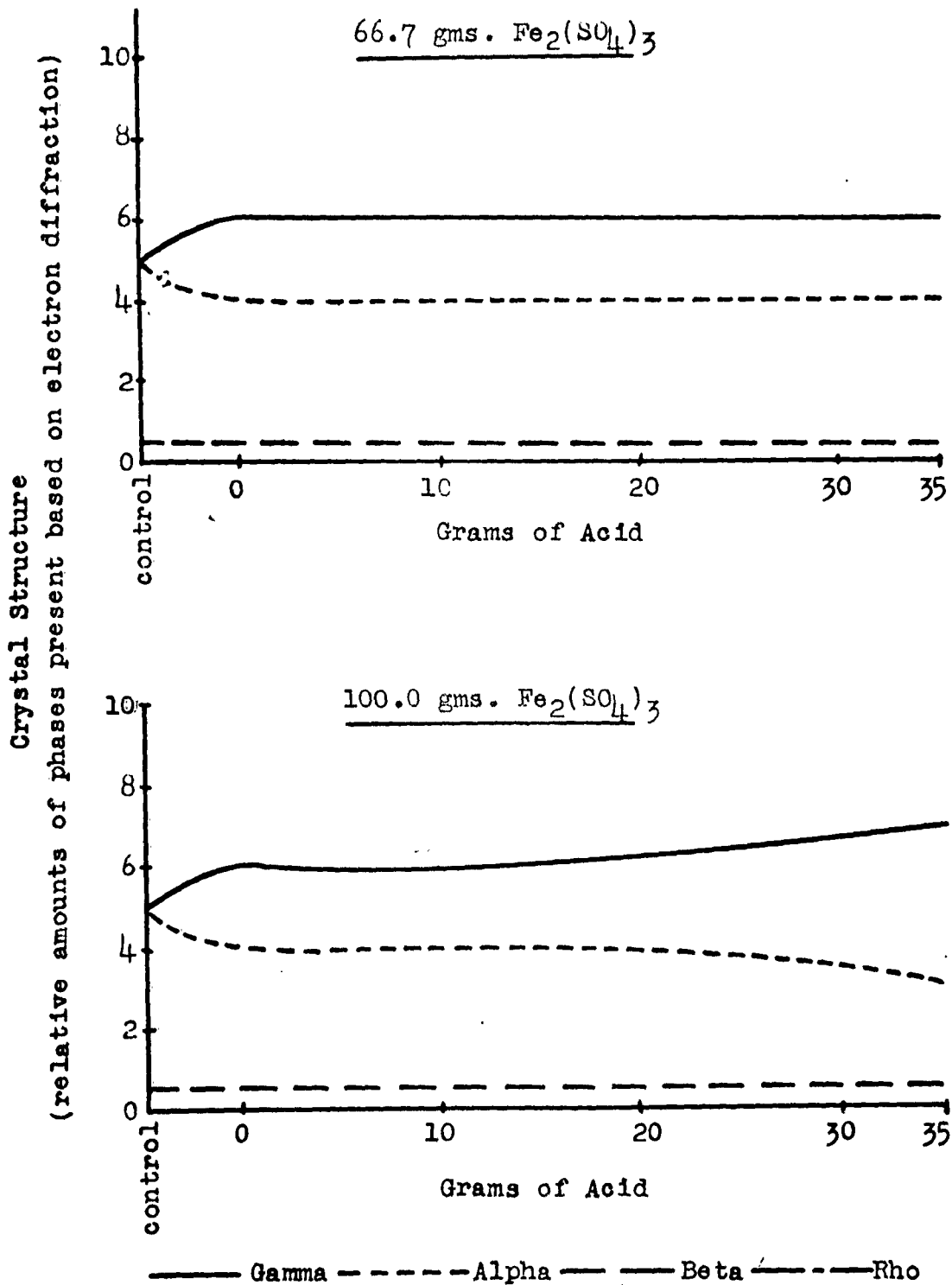


FIGURE 6 (Cont.)

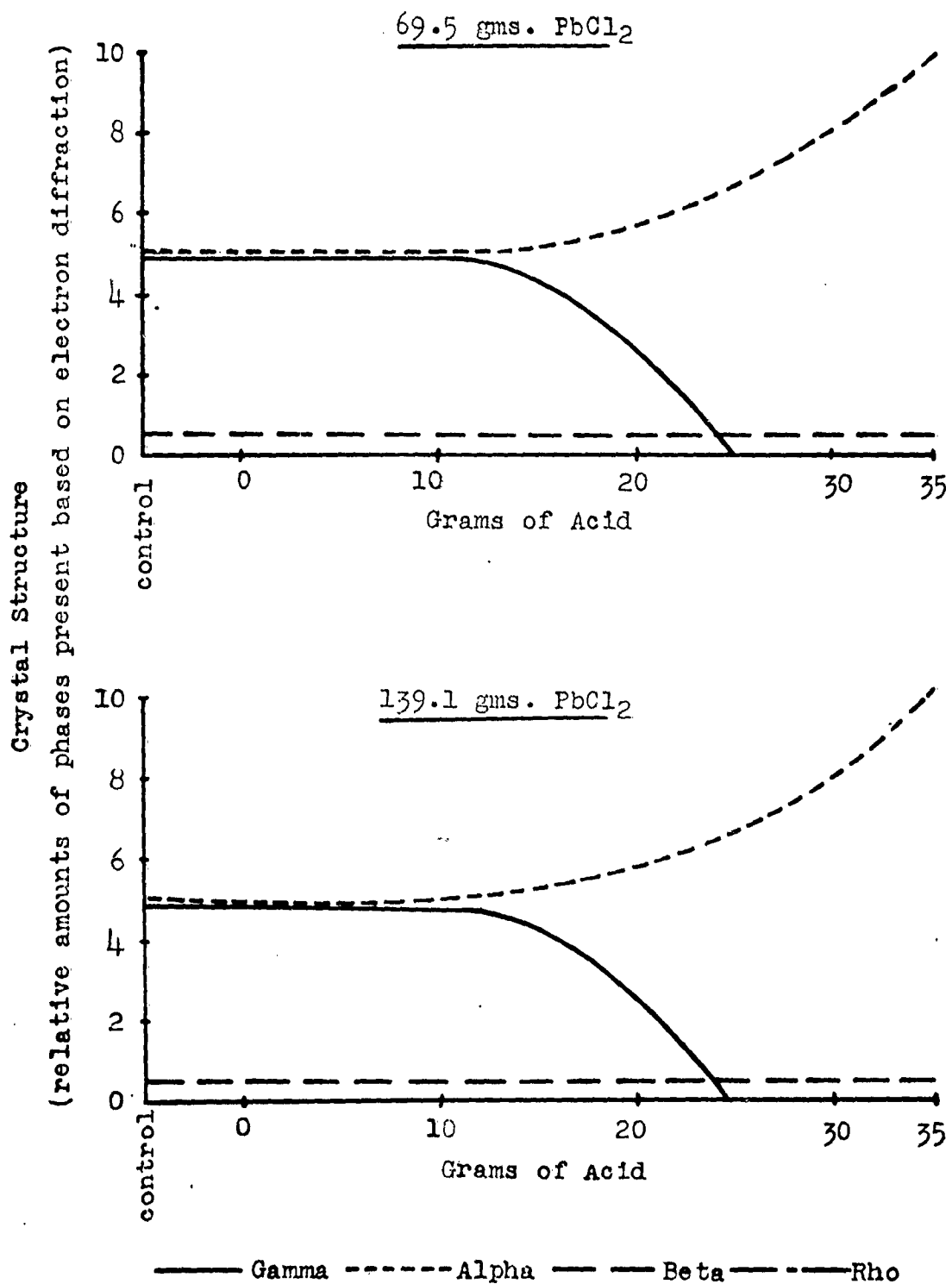


FIGURE 6 (Cont.)

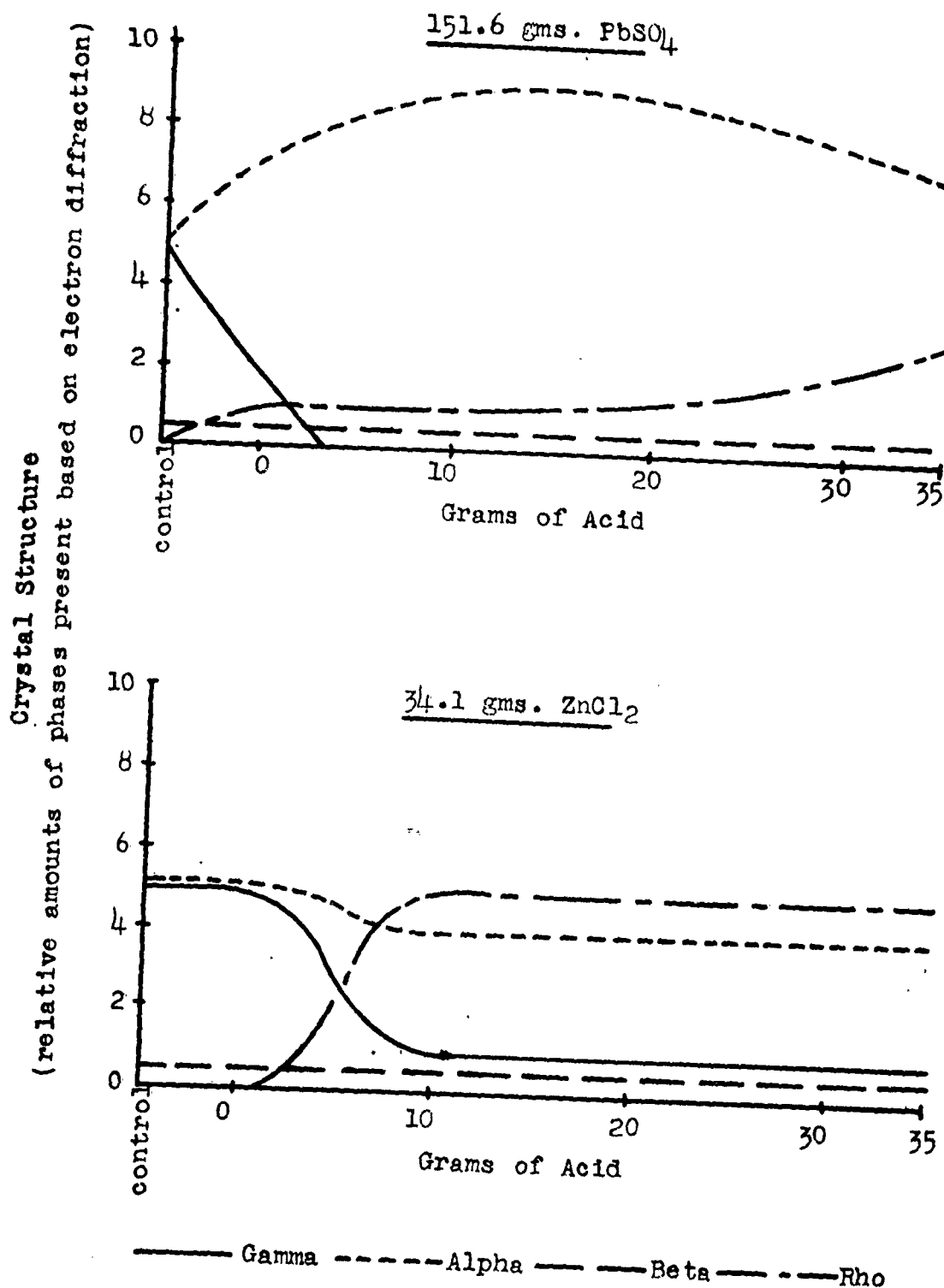


FIGURE 6 (Cont.)

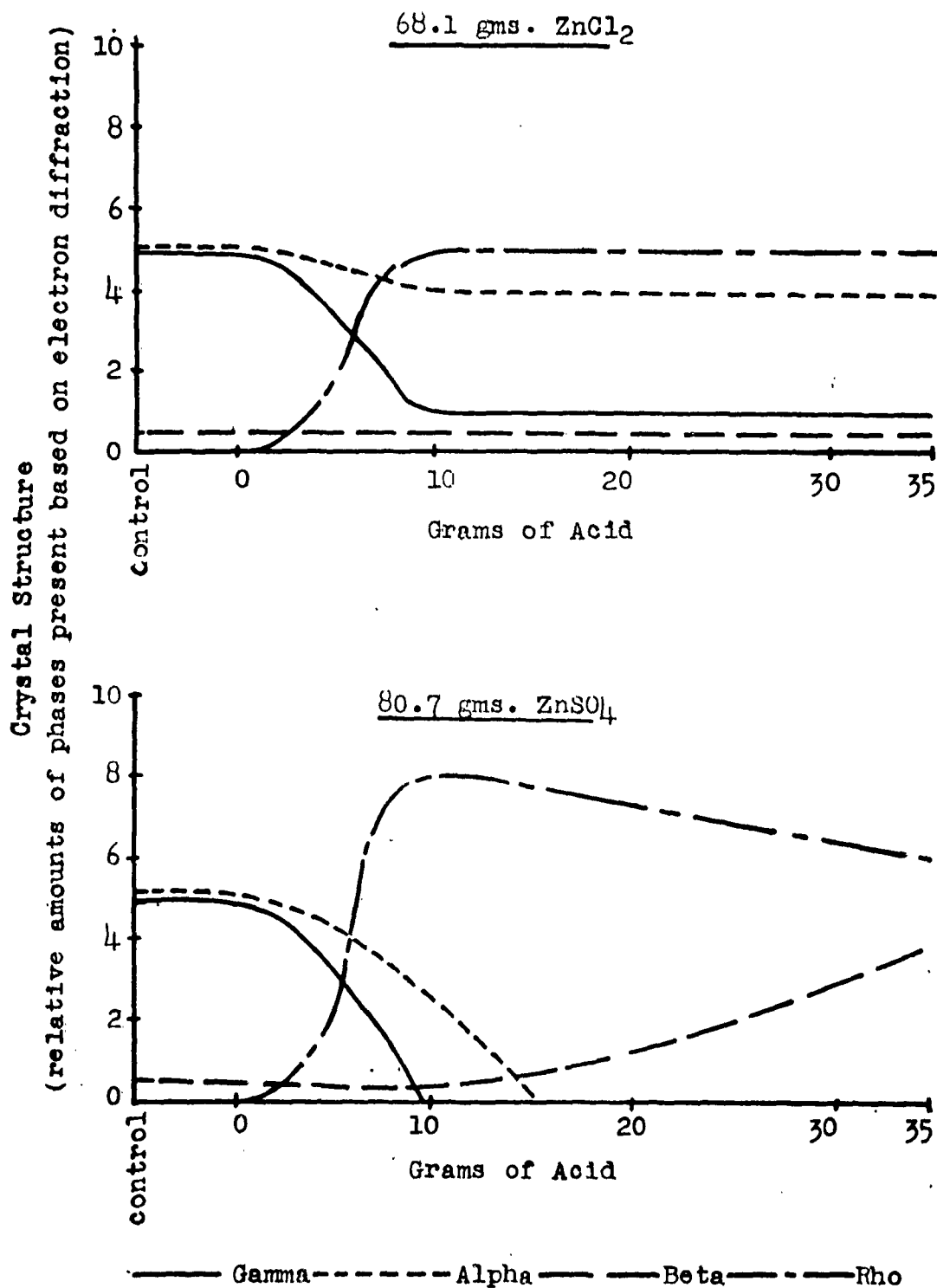


FIGURE 6 (Cont.)

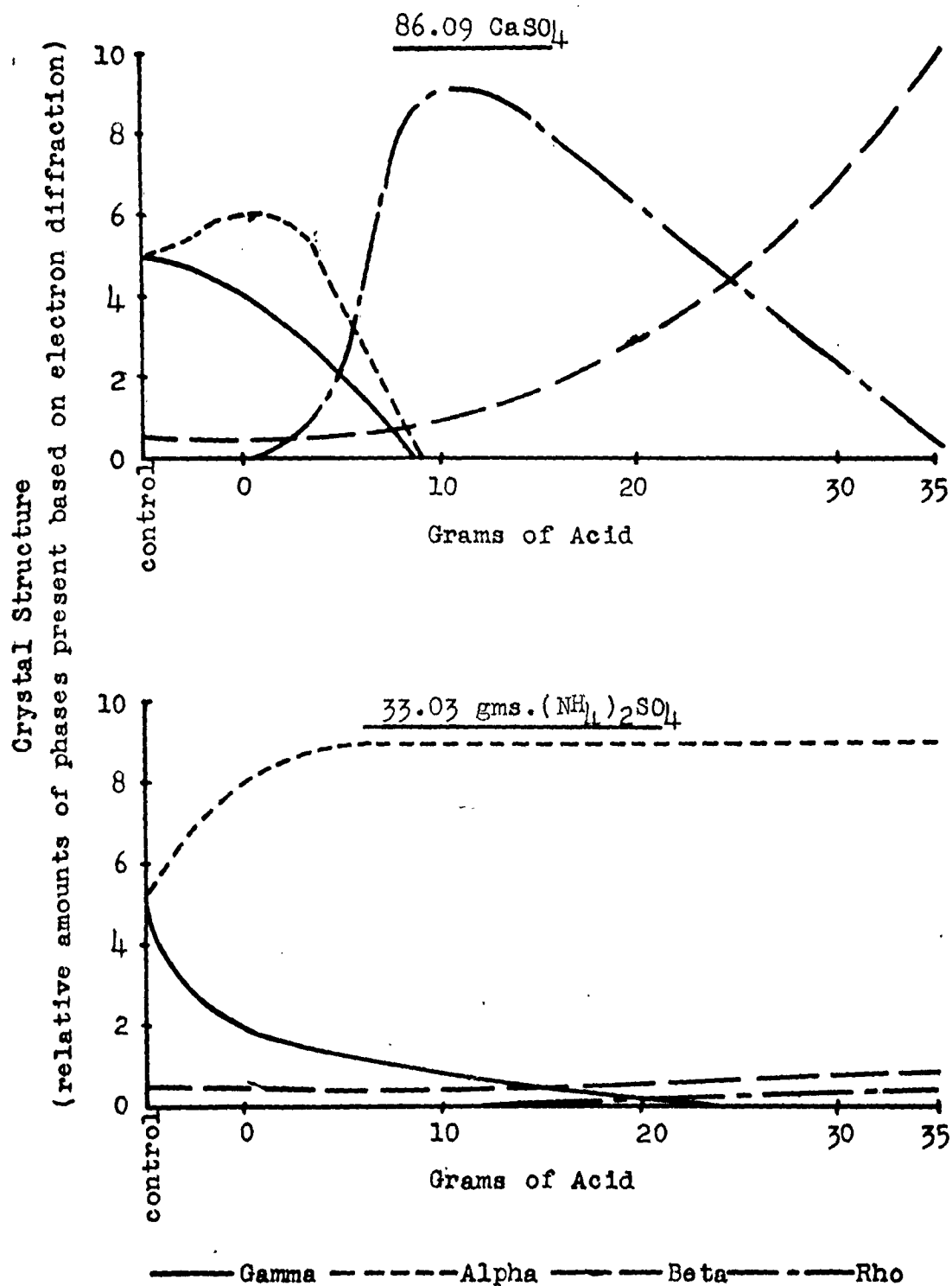


FIGURE 6 (Cont.)

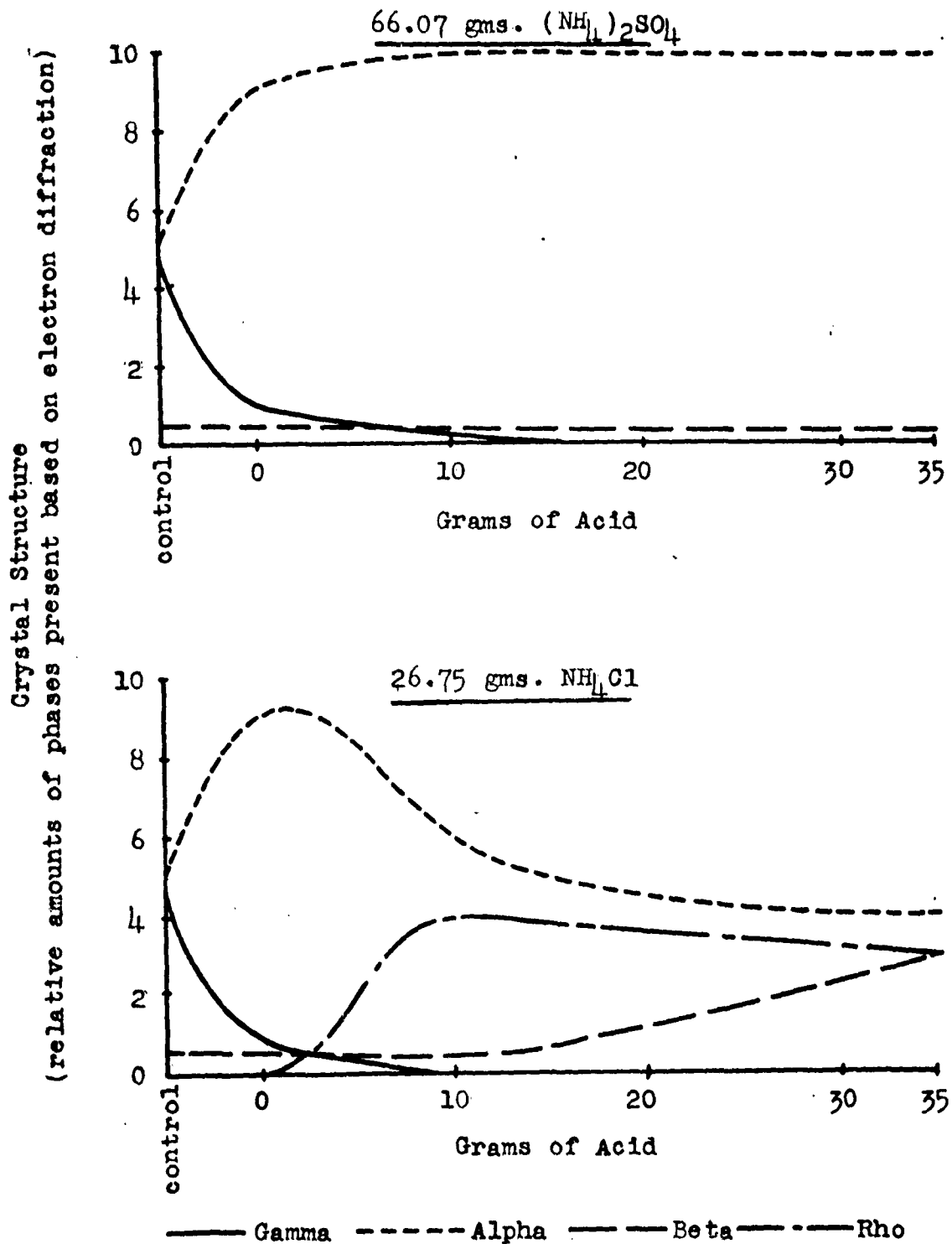


FIGURE 6 (Cont.)

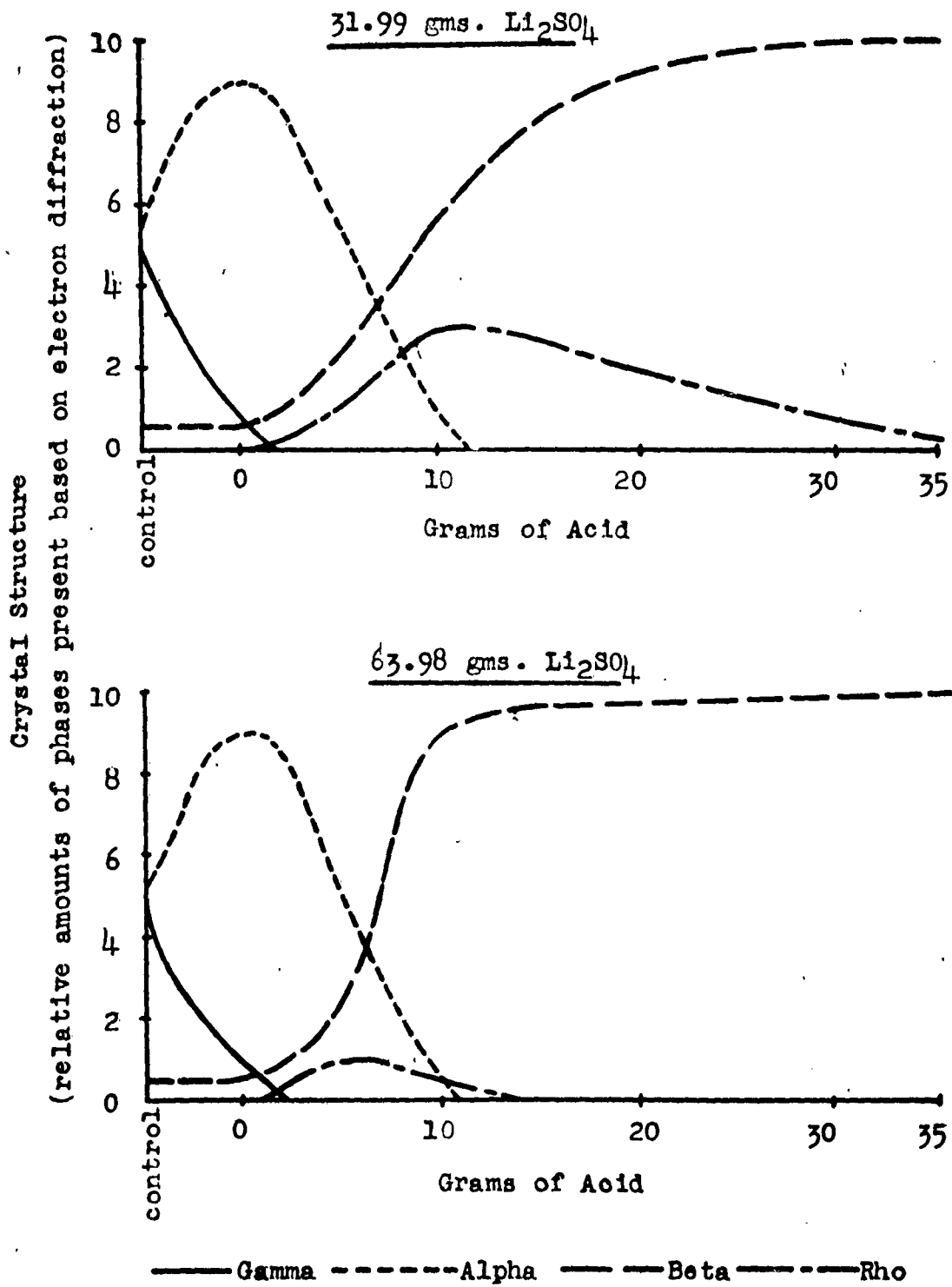


FIGURE 6 (Cont.)

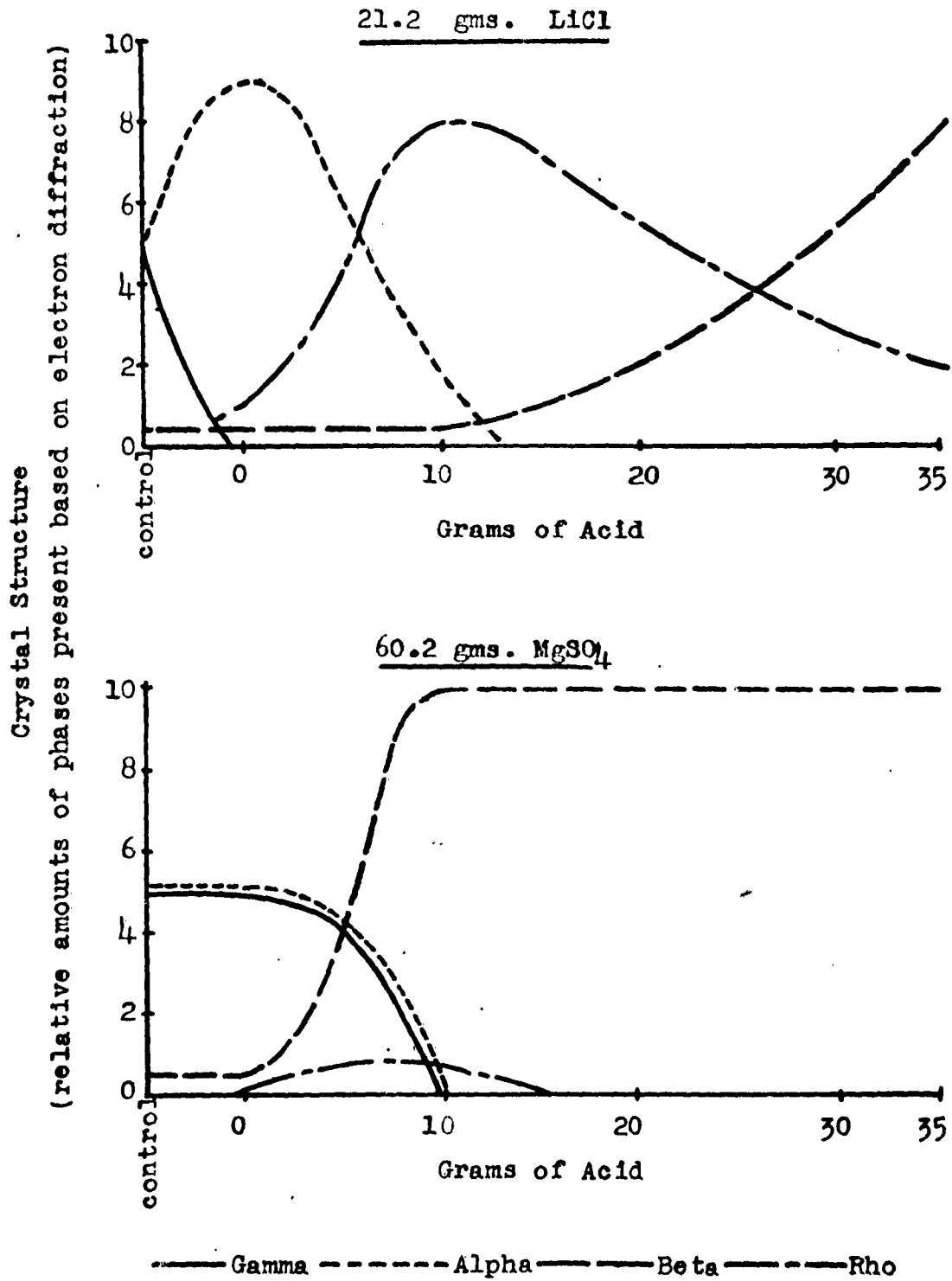
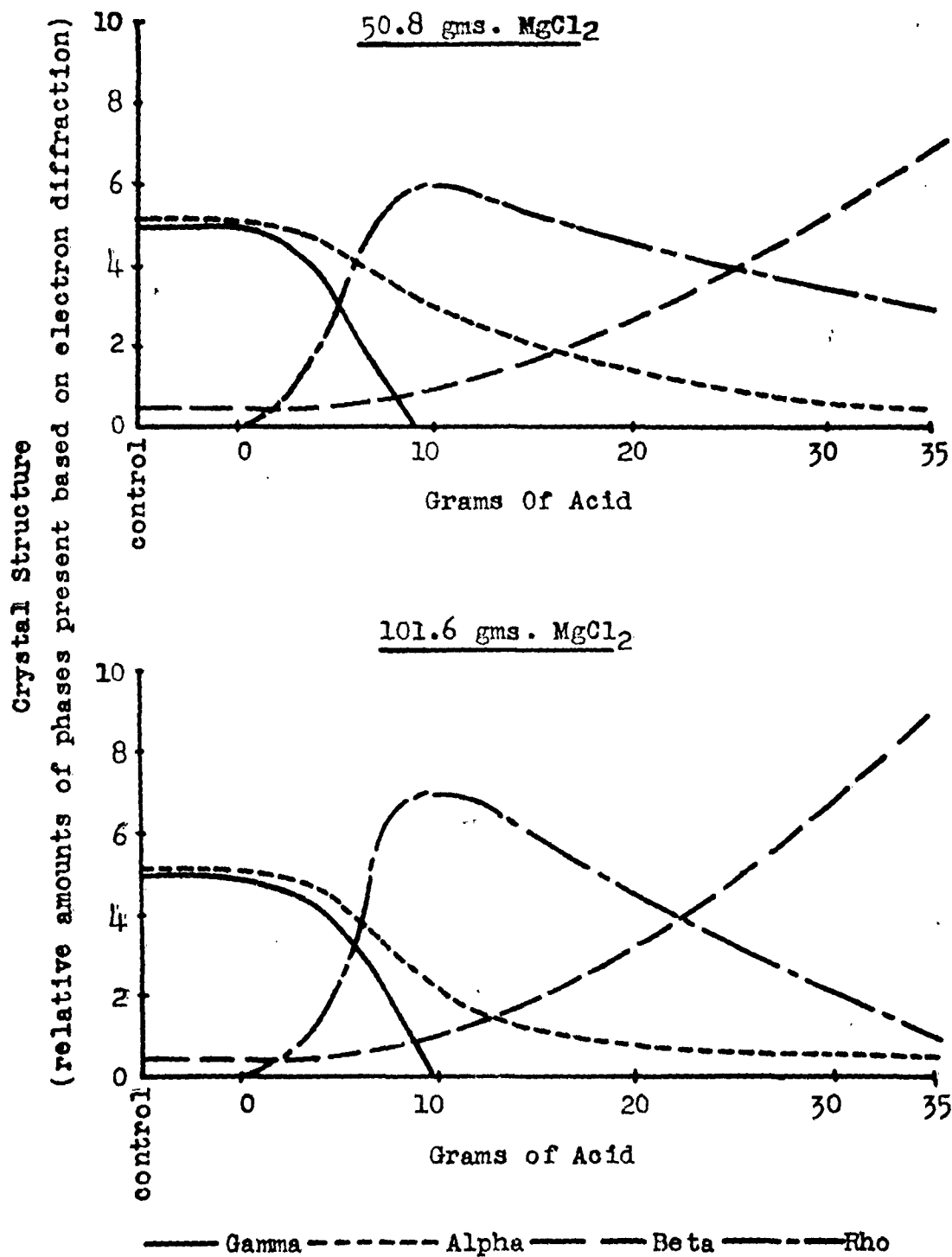
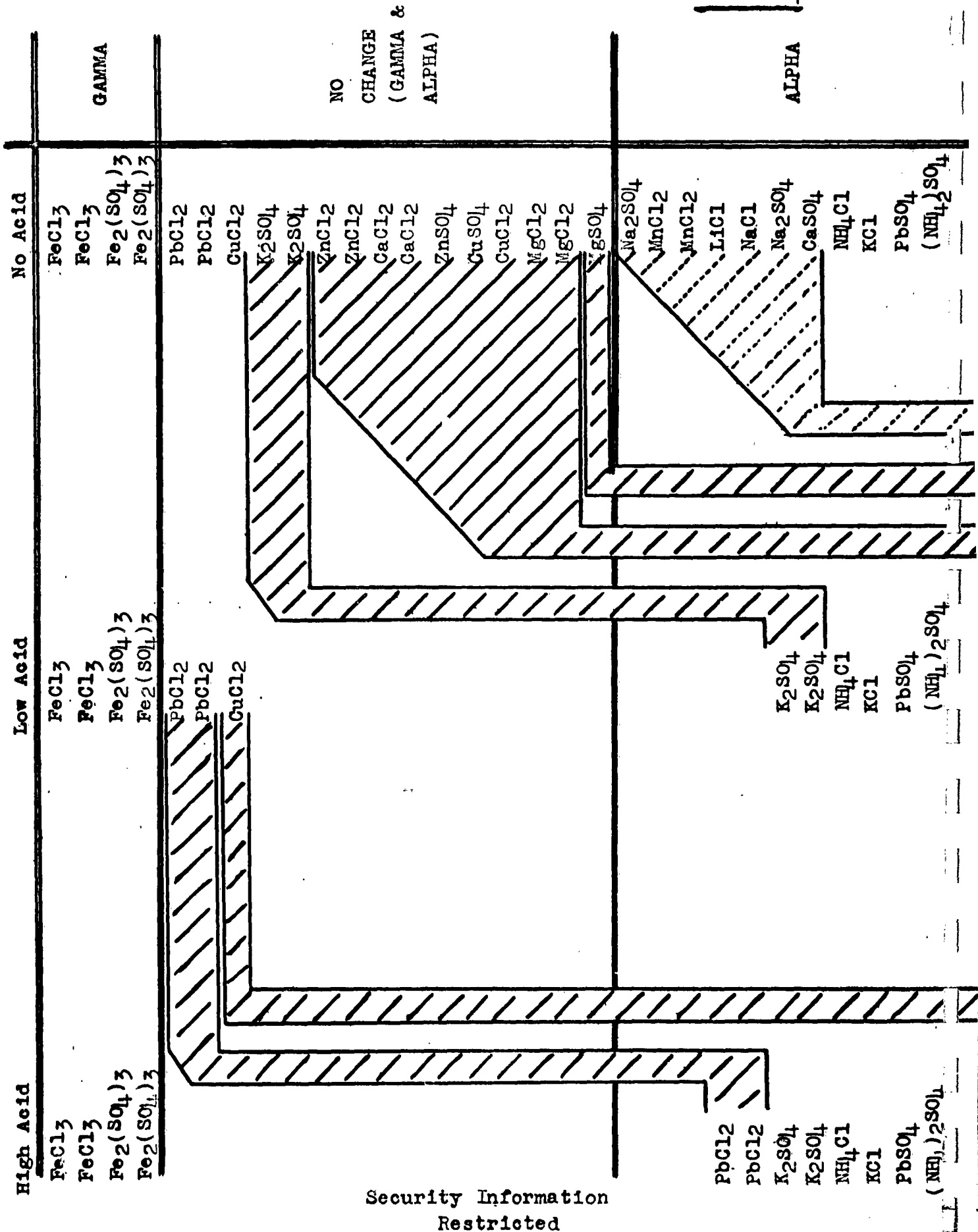


FIGURE 6 (Cont.)



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FIGURE 7



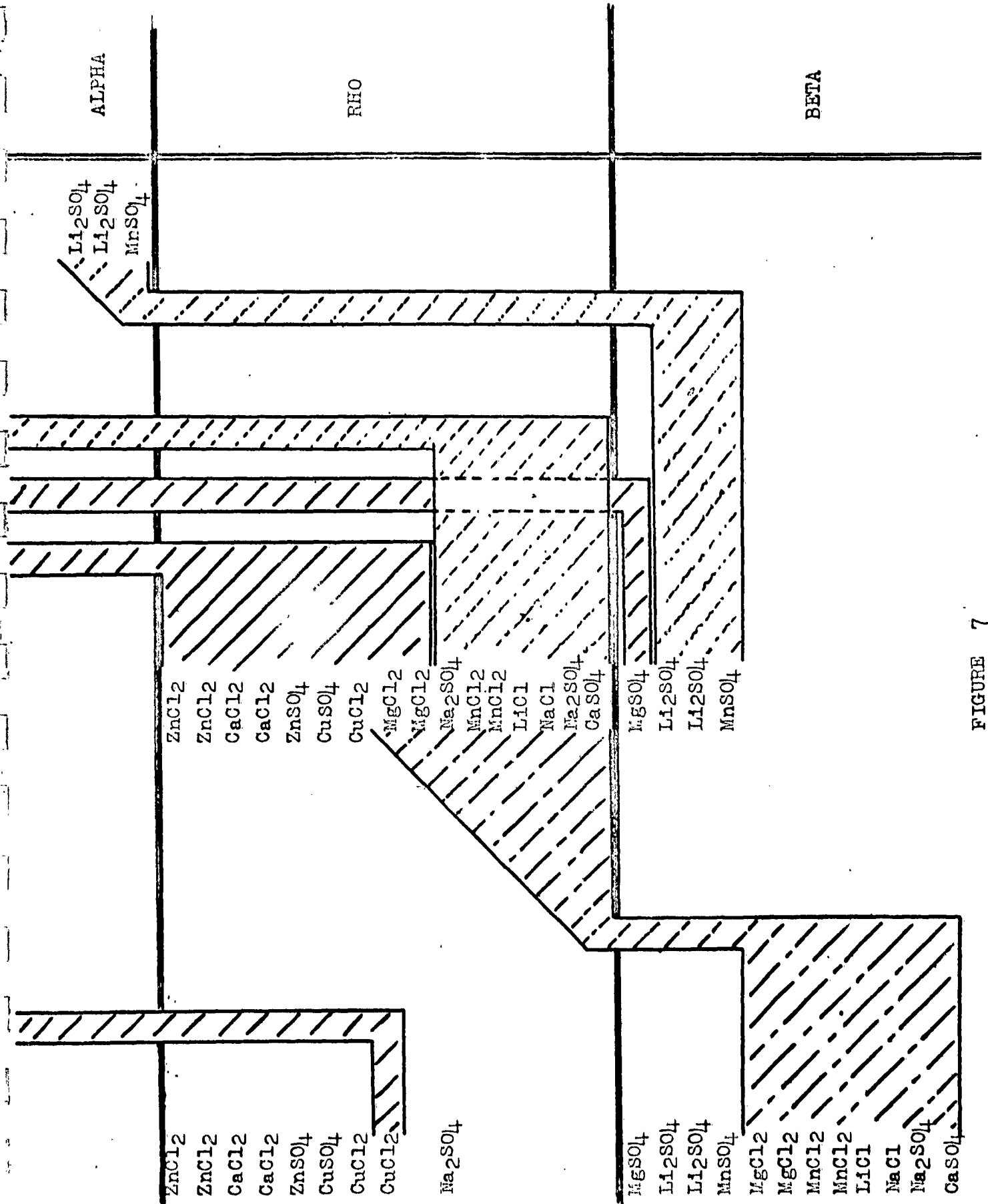


FIGURE 7



Part III - Separator Materials

It is known that the voltage drop of batteries stored under tropical conditions is much more severe than the voltage drop associated with batteries stored at room temperature. Early in the contract, experiments were started to determine what effect conventional starch separators had on the delayed voltage characteristics of batteries placed on tropical storage. It was known that African ore and French Ergogene ore do not lose voltage when stored at room temperature in a sealed glass jar as a mix with Shawinigan black. This had been tested over a considerable period of time. These ores were therefore selected for preliminary investigation. Conventional D size cores were tamped from the ores. Some of the ores were stored in glass jars alone, others were cooked in starch in the jar without a zinc anode present, and others were assembled into cells in the normal manner.

The results of this study are recorded after three months in Figure #1.

The data indicate a small but definite voltage drop in the ore mixes stored by themselves. This may be attributed to either a reduction in the manganese dioxide caused by the Shawinigan black or a change in crystal structure phase resulting from the elevated temperatures.

It appears from this work that for a period of one or two months at 113°F. (depending on the ore evaluated) that both a pH change and reduction of manganese dioxide must be responsible for the voltage decrease in cells of normal construction. The increase in pH of the electrolyte can be attributed to the corrosion of the zinc. However, after this period the pH within the cell reaches a nearly constant level and reduction of the manganese dioxide by the starch becomes the more important factor.

Hypothetical curves for this analysis are shown in Figure #2.

To make certain that the starch itself was not responsible for altering the pH, a blank was run in which battery electrolyte and starch were cooked together at a given pH and then stored for a period of two months at 113°F. It was found upon re-measuring the pH that no appreciable change had taken place. Actually the pH had dropped from an initial value of 3.6 to a value of 3.2. This indicates that the voltage drop of the manganese dioxide mixes stored in contact with the starch alone was due entirely to the reduction of the manganese dioxide by the starch. Chemical action accelerated by high temperature causes serious voltage drops at temperatures of 130°F. and 160°F. presenting a serious problem to high storage conditions.

In order to prove that a conventional separator will substantially reduce the voltage of manganese dioxide, the individual components of a paste separator (corn starch, potato starch, flour, and electrolyte), were tested. Several different types of manganese dioxide (African ore, Baker's Analytical (pyrolusite), Burgess Chem ore, Burgess Electro ore and cryptomelane ore made by leaching light hydrate in 20% zinc chloride solution) were used in these

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tests to determine if the structural form of manganese dioxide contributed in any manner to the amount of voltage reduction.

The effect of separator materials was tested in the following manner. Using a conventional electrolyte as a wetter, cores of AA size were made from 100% mixes (7/1 - ore/black) of the five manganese dioxides listed above. The separator materials being tested, namely, corn starch, potato starch, and flour, were then made into pastes using the same electrolyte that was used as a wetter when making the manganese dioxides into mixes. The AA cores were placed in these separator pastes in glass jars and the pastes gelled by heating. The glass jars were then sealed and placed in storage at 113°F. Glass jars were used in order to eliminate the problem of pH change caused by the presence of a zinc anode. The paste gel surrounding the AA cores was about five times the thickness found in a conventional cell. This thickness was used in order that sufficient separator would be present to give substantial evidence of reduction in the voltage of manganese dioxide. Control samples for each type of manganese dioxide were also stored at 113°F. The control consisted of samples of the individual mixes, stored in glass jars, i.e. with only electrolyte present.

The voltage of the different samples was measured initially and after three days at 70°F, and after two weeks and one month at 113°F. The table and graphs showing one month reduction in voltage of these samples are given in Figure #3, while Figure #4 in the series shows voltage reduction at the end of six months with African ore. Data accumulated over a twelve month period for these samples are given in Figure #5 along with the graphic chart of the effect of corn starch samples on these ores.

These results show that a considerable drop in voltage is caused by the materials tested. Greatest reduction in voltage is evidenced in the case of the flour separator while potato starch appears to be the best. The graphs show that the reduction in voltage is very rapid under the conditions present over the first part of the storage period but has a tendency to level out during the latter part of the storage period.

The data indicate that the greater the degree of activation of the manganese dioxide the greater will be the voltage reduction which takes place. For example, African ore stored in contact with corn starch underwent a voltage decrease of 0.22 volts, while Burgess Electro ore underwent a decrease of 0.38 volts under the same conditions. The initial voltage of the Burgess Electro ore sample was approximately 0.10 volts above the initial voltage of the African ore sample, while after twelve months storage at 113°F it was approximately 0.05 volts below the voltage of the African ore sample.

Starch chemistry indicates that once oxidation and breakdown of the separator material begins, it continues with greater ease. A higher voltage manganese dioxide should, therefore, give rise to an increased initial oxidation and breakdown.

The voltage readings of the cores in contact with separator materials

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were measured in the following manner. One leg of a modified salt bridge (see Figure 1) was filled with the same electrolyte used in the samples, and was placed in contact with the separator materials in the glass jars. The second leg of this salt bridge (containing saturated KCl solution) was in contact with a calomel half cell. A lead wire from the calomel cell to the negative emf terminal of a potentiometer and a lead wire from the carbon rod of the AA core in contact with the separator material to the positive emf terminal of the potentiometer completed the circuit. The voltage of the manganese dioxide minus that of the calomel cell was read directly on the potentiometer. Thus by adding the voltage of the calomel cell (0.242V) to the reading obtained from the potentiometer, the voltage of the manganese dioxide was obtained. Since the potentiometer used was a null instrument, no drain was put on the sample. Thus readings can be repeated as often as desired with no destructive effects to the samples.

The voltage of the control samples was measured in a slightly different manner since they were stored as mixes rather than as tamped cores. The procedure used for determining the voltage of these control samples was as follows. A hole, approximately  $3/32$ " in diameter and  $1/8$ " deep, was drilled in a carbon rod and a small quantity of mix solidly tamped into this cavity. This rod had a brass cap on the other end to insure good contact. This assembly was then pressed tightly against an absorbent piece of Crocker-Burbank tan saturating paper, the paper first having been saturated with the electrolyte used to wet the mixes initially. The leg of the modified salt bridge containing electrolyte was also pressed against the saturated paper a slight distance away from the carbon rod assembly. The saturated paper made a conductive path between them. The measurement of the voltage of the sample was then carried out as described in the preceding paragraph.

A study was made to determine if the starch had to be in contact with the manganese dioxide. The data are shown in Figure 6. It can be seen that when the manganese dioxide was separated from the starch by an electrolyte barrier a smaller decrease in voltage resulted than when the starch was in direct contact. However, this difference is quite small when compared to the overall reduction in voltage which occurs. The study definitely shows that the starch does not have to be in contact with the manganese dioxide in order to seriously reduce its voltage and that the major proportion of the voltage reduction is caused by some soluble components already present in the starch or by some component formed on the acid action of the electrolyte on the starch.

A study was made to determine the effect of paste thickness on the voltage of manganese dioxide. The data are shown in Figure 7. It can be seen that the amount of reduction in voltage varies directly with the paste thickness. This is probably due to a large percentage of soluble material being present due to the extra starch.

Figure 8 is a study of the effect of varying the electrolyte pH on the oxidation of flour (manganese dioxide voltage reduction) when stored as a

paste in contact with manganese dioxide at 113°F. Control samples were made by wrapping AA size cores with dynel cloth and storing them in an electrolyte whose pH had been adjusted by the addition of ammonium chloride. The test samples were made by storing AA size cores in a flour paste made with the adjusted pH electrolyte. Electrolytes from a pH of 3.8 to a pH of 7.9 were studied.

As would be expected, the initial voltage of the manganese dioxide decreases as the pH rises. After six months of storage at 113°F., the manganese dioxide stored in contact with the flour separator shows the greatest voltage reduction at the lowest pH, and the amount of reduction decreases as the pH is increased, as illustrated by the accompanying chart. The formation of diamine occurs at about pH = 5.2 with the electrolyte used.

Above the pH of 5.2 the voltage reduction is essentially constant. The varying pH of the electrolyte does not appear to significantly affect the voltage reduction of the control samples.

This study along with the study of the effect of electrolyte pH on the voltage of zinc indicates the cells utilizing a pH adjusted electrolyte may have benefits.

The fact that voltage reduction is lower at a less acid pH tends to prove that at least some of the voltage reduction is due to components formed by the acid action of the electrolyte on the starch molecule.

The search for a suitable separator included a wide variety of possible materials which were tested on storage at 113°F. and 160°F. in a manner previously described to determine the extent to which they will reduce the manganese dioxide.

These materials included various starches, gums, proteins and glutes. The results of these tests showing the most promising materials are tabulated in Figure #9 for 113°F., and in Figure #10 for 160°F.

The proteins and glutes were tested in much the same manner as the starch materials. Since the proteins and glutes are for the most part only slightly soluble in electrolyte, a saturated solution (containing about 1% of the material) was made up. Double AA cores were tamped from an African ore mix (7/1 ore/black) and wrapped with Dynel cloth, which is a non-woven fabric having no reducing effect on manganese dioxide. The wrapped cores were then placed in sample bottles containing the various saturated solutions and placed on storage. Results indicate that the proteins and glutes (at least in the amounts used) do not reduce the voltage of manganese dioxide as greatly as do corn or potato starch. In addition, both proteins and glutes show good inhibiting properties and it is quite possible that they may be incorporated into a separator material.

Those of a protein nature do not form gels and therefore it would be

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necessary to use them with some other separator material, probably in the capacity of an inhibitor.

On the basis of this evaluation work a definite correlation can be set up in regard to the materials tested. As a result the following classifications can be used in regard to separator materials.

(a) The first classification is headed by conventional corn and potato starches and includes those materials which cause a voltage decrease of approximately 0.2 to 0.25 volts over a period of one year. This class includes almost all of the various starch type materials.

(b) The second classification includes the various flours and shows a voltage decrease of approximately 0.25 to 0.30 volts.

(c) The third classification includes materials which cause comparatively little voltage reduction during the storage period. This classification includes such materials as proteins, glutens and most of the gum type materials. These materials cause a voltage reduction of approximately 0.10 to 0.15 volts during the storage period.

The above classifications are based on the results of twelve months tests conducted on separator materials in contact with African ore. The same classes exist when other ores are used but will vary in the degree of voltage reduction.

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Conclusions

1. Starch and flour materials substantially reduce manganese dioxide.
2. Flour reduces manganese dioxide more than starch.
3. The voltage reduction of a manganese dioxide when stored in contact with a conventional separator material will be greater as the degree of activation of the ore is increased.
4. Increasing the amount of starch in contact with manganese dioxide increases the voltage reduction of the ore.
5. If the pH of the electrolyte used in a starch paste is increased, the percentage of voltage drop in manganese dioxide is decreased until the pH at which diammine forms is reached. After this point the reduction is essentially constant with a pH rise.
6. Most starch materials will not retain their gel structure when stored as paste mixture in contact with manganese dioxide for extended periods at 160°F.
7. The reduction in voltage of manganese dioxide when stored in contact with starch is due to some soluble product initially present in the starch and/or some product formed by the acid action of the electrolyte on the starch.
8. Reduction in voltage of manganese dioxide due to starch oxidation is rapid during the early portions of storage (one month at 113°F. and two weeks at 160°F). The voltage tends to level out with little change in the later stages of storage.

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TABLES AND CHARTS

PART III

STABILITY OF SEPARATOR MATERIALS

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FIGURE 1

Manganese Dioxide Voltage Decrease Due To Oxidation Of Starch Separator

Cell Construction	Voltage Results-Average of Three Readings All readings made at 70° F.							
	French Ergogene Ore				African Ore			
	Initial @ 70° F.	1 Mo @ 70° F.	2 Mos @ 70° F.	3 Mos @ 70° F.	Initial @ 70° F.	1 Mo @ 70° F.	2 Mos @ 70° F.	3 Mos @ 70° F.
Mix tamped into "D" size slug with no pencil. Slug stored in sealed glass jar without separator or anode.	1.82 v.	1.80 v.	1.78 v.	1.70 v.	1.67 v.	1.66 v.	1.65 v.	1.60 v.
Mix tamped into "D" size slug with no pencil. Slug stored in excess flour-starch paste separator with no anode present.	1.82	1.63	1.57	1.45	1.67	1.58	1.58	1.50
Mix tamped into conventional "D" size bobbin. Stored in excess flour-starch paste separator with no anode present.	1.82	1.63	1.56	1.42	1.67	1.58	1.58	1.51
Mix tamped into conventional "D" size bobbin. Bobbin stored with no anode or separator present	1.82	1.79	1.74	1.65	1.67	1.65	1.64	1.58
Conventional "D" cell stored for desired period. Bobbin removed from can at end of storage and made into fresh cell.	1.82	1.62	1.58	1.57	1.67	1.58	1.56	1.54
Conventional "D" size bobbin stored in excess flour-starch separator with no anode. At end of storage time made into fresh cell.	1.82	1.65	1.57	1.48	1.67	1.61	1.60	1.55

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FIGURE 1 (Cont.)

Manganese Dioxide Voltage Decrease Due To Oxidation Of Starch Separator

Cell Construction	Voltage Results-Average of Three Readings All readings made at 70°F.							
	French Ergogene Ore				African Ore			
	Initial @ 70°F.	1 Mo 113°F	2 Mos 113°F	3 Mos 113°F	Initial @ 70°F.	1 Mo 113°F	2 Mos 113°F	3 mos 113°F
Conventional "D" size bobbin stored with no separator or anode. Bobbin removed at end of storage and made into fresh cell.	1.82 v.	1.80 v.	1.77 v.	1.71 v.	1.67 v.	1.68 v.	1.68 v.	1.63 v.
Conventional "D" size bobbin stored in the presence of glass wool and ZnCl <sub>2</sub> - NH <sub>4</sub> Cl solution.	1.82	1.75 pH of sol. 3.6	1.73 pH of sol. 3.33					
Conventional "D" size bobbin stored in the presence of glass wool, ZnCl <sub>2</sub> -NH <sub>4</sub> Cl solution and a zinc mesh anode.	1.82	1.71 pH of sol. 4.2	1.59 pH of sol. 5.3					

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FIGURE 2

Theoretical Curves of Voltage Decrease Due to the  
Effect of Starch Oxidation and the Change of pH.

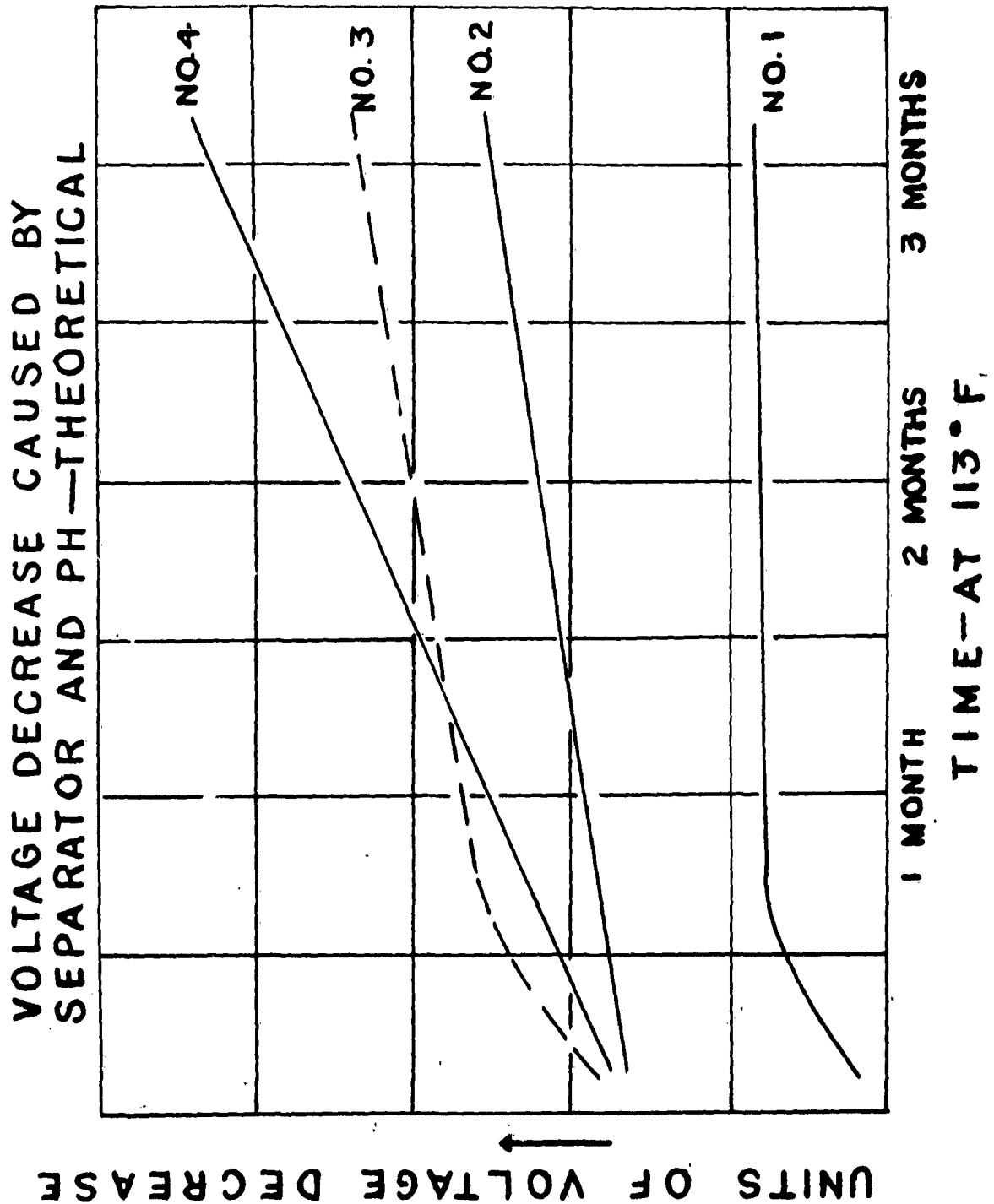
Curve No. 1 - Voltage decrease due to the change  
of pH (corrosion).

Curve No. 2 - Voltage decrease due to oxidation  
of starch only - normal starch  
separator thickness (no pH factor).

Curve No. 3 - Voltage decrease due to change in  
pH plus voltage decrease due to  
oxidation of starch - (normal cell).

Curve No. 4 - Voltage decrease due to oxidation  
of starch only - excess starch  
(no pH factor).

FIGURE 2 (Cont.)



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FIGURE 3

Study of Voltage Decrease of Depolarizer Mixes Due to the Oxidation and  
Breakdown of Separator Materials

Depolarizer Mix	Separator Materials	Voltage Readings				Voltage Drop After 1 month
		Initial	3 days @ 70°F.	2 weeks @ 113°F.	1 month @ 113°F.	
100% African Ore	Control-only Electrolyte	0.920 v.	-----	-----	0.914 v.	0.006 v.
	Corn starch	0.920 v.	0.863 v.	0.812 v.	0.800 v.	0.120 v.
	Potato Starch	0.920 v.	0.884 v.	0.821 v.	0.805 v.	0.115 v.
	Flour	0.920 v.	0.788 v.	0.724 v.	0.724 v.	0.196 v.
100% Bakers Pyrolusite	Control-only Electrolyte	0.895 v.	-----	-----	0.894 v.	0.001 v.
	Corn starch	0.895 v.	0.812 v.	0.736 v.	0.716 v.	0.179 v.
	Potato Starch	0.895 v.	0.836 v.	0.776 v.	0.740 v.	0.155 v.
	Flour	0.895 v.	0.775 v.	0.695 v.	0.673 v.	0.222 v.
100% Burgess Chem. Ore	Control-only Electrolyte	0.995 v.	-----	-----	0.980 v.	0.015 v.
	Corn starch	0.995 v.	0.902 v.	0.789 v.	0.744 v.	0.249 v.
	Potato starch	0.995 v.	0.922 v.	0.804 v.	0.750 v.	0.245 v.
	Flour	0.995 v.	0.813 v.	0.686 v.	0.665 v.	0.330 v.
100% Burgess Electro Ore	Control-only Electrolyte	1.025 v.	-----	-----	1.025 v.	0.000 v.
	Corn starch	1.025 v.	0.957 v.	0.816 v.	0.756 v.	0.269 v.
	Potato starch	1.025 v.	0.982 v.	0.812 v.	0.762 v.	0.263 v.
	Flour	1.025 v.	0.855 v.	0.754 v.	0.684 v.	0.341 v.
100% Cryptomelane (Lt. Hydrate) leached in 20% ZnCl <sub>2</sub> sol	Control-only Electrolyte	0.962 v.	-----	-----	0.931 v.	0.031 v.
	Corn starch	0.962 v.	0.855 v.	0.738 v.	0.705 v.	0.257 v.
	Potato starch	0.962 v.	0.881 v.	0.761 v.	0.670 v.	0.292 v.
	Flour	0.962 v.	0.781 v.	0.686 v.	0.670 v.	0.292 v.

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FIGURE 3 (Cont.)

The voltage of Manganese Dioxides in Contact with Separator  
Materials versus Storage Time at 113°F.

Curve No. 1 - Control, manganese dioxide mix (7/1-ore/black)  
Stored in contact with electrolyte only.

Curve No. 2 - Manganese dioxide mix (7/1-ore/black) stored in  
contact with a corn starch-electrolyte gel.

Curve No. 3 - Manganese dioxide mix (7/1-ore/black) stored in  
contact with a potato starch-electrolyte gel.

Curve No. 4 - Manganese dioxide mix (7/1-ore/black) stored in  
contact with a flour- electrolyte gel.

FIGURE 3 (Cont.)

Voltage of African Ore in Contact with Separator  
Materials vs. Storage Time.

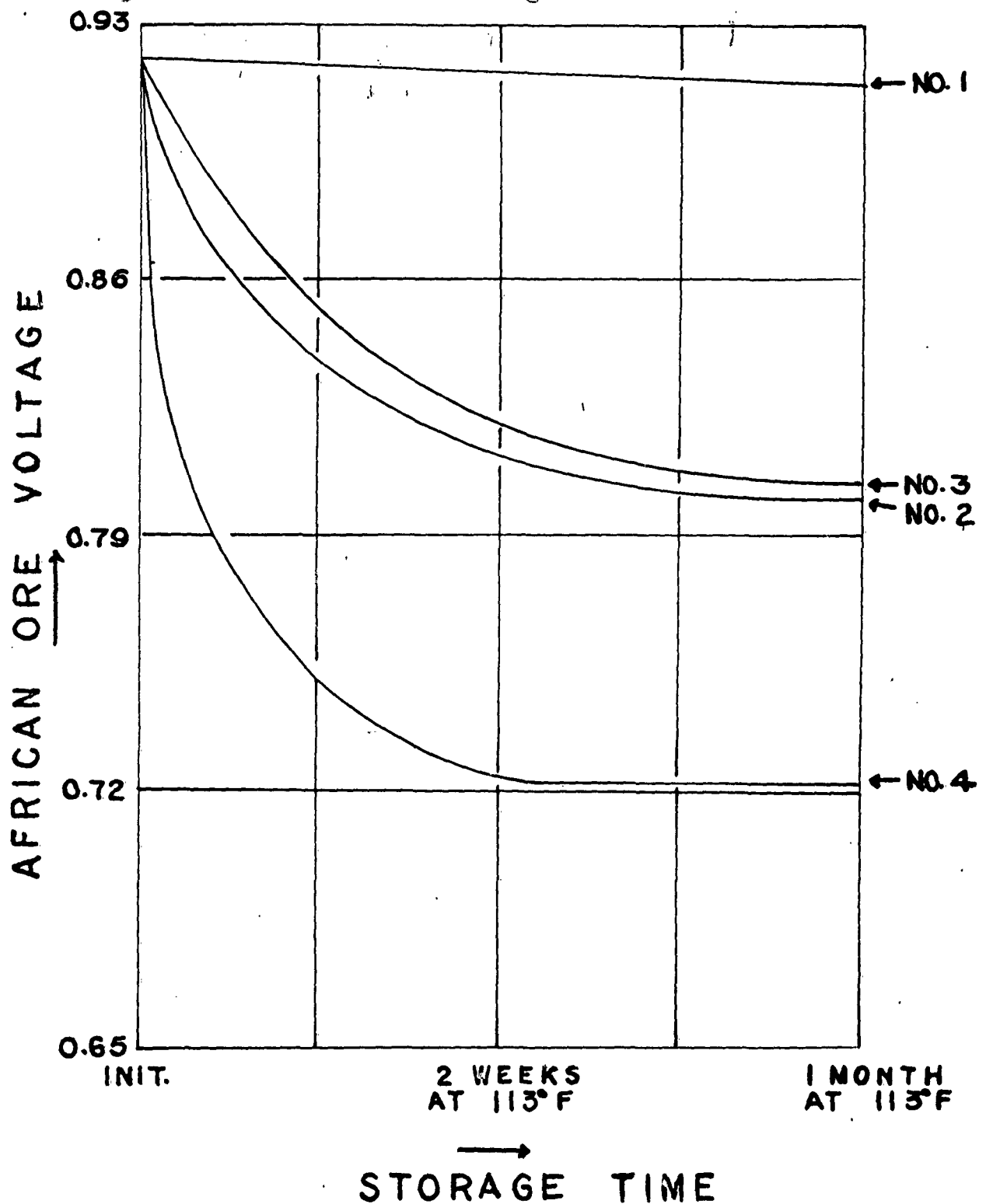


FIGURE 3 (Cont.)

Voltage of Pyrolusite Ore in Contact with Separator  
Materials vs. Storage Time.

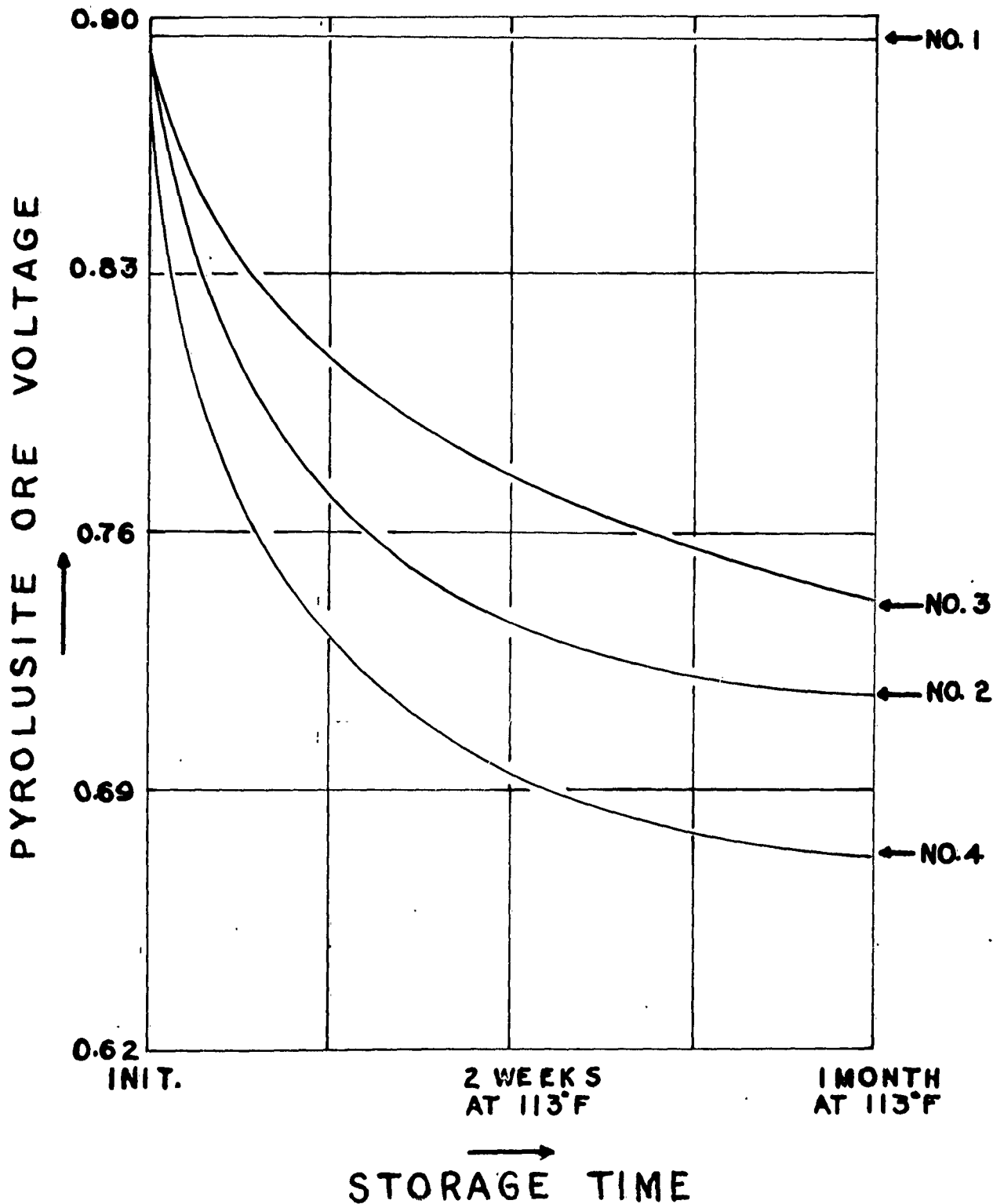
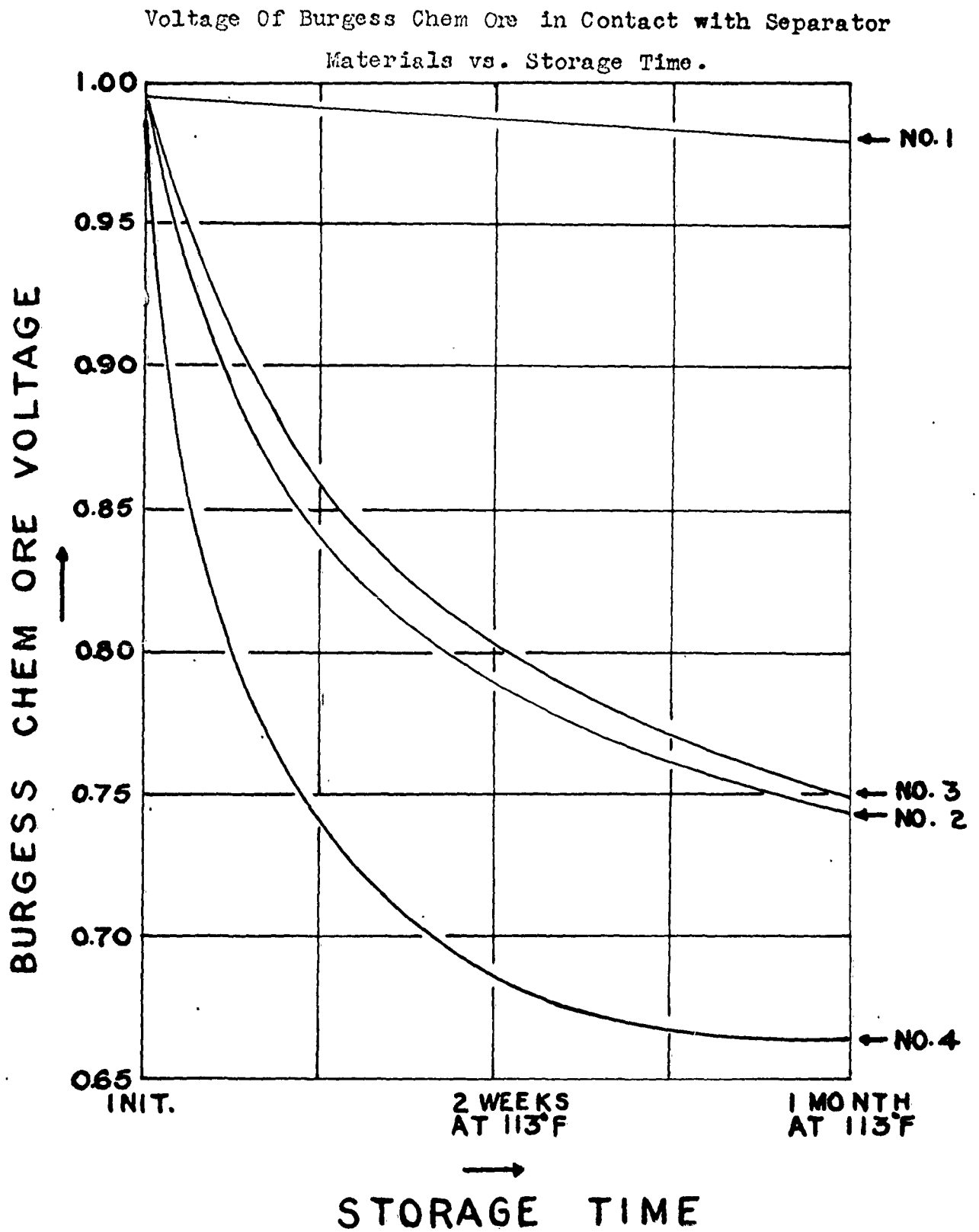


FIGURE 3 (Cont.)



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FIGURE 3 (Cont.)

Voltage of Burgess Electro Ore in Contact with  
Separator Materials vs. Storage Time.

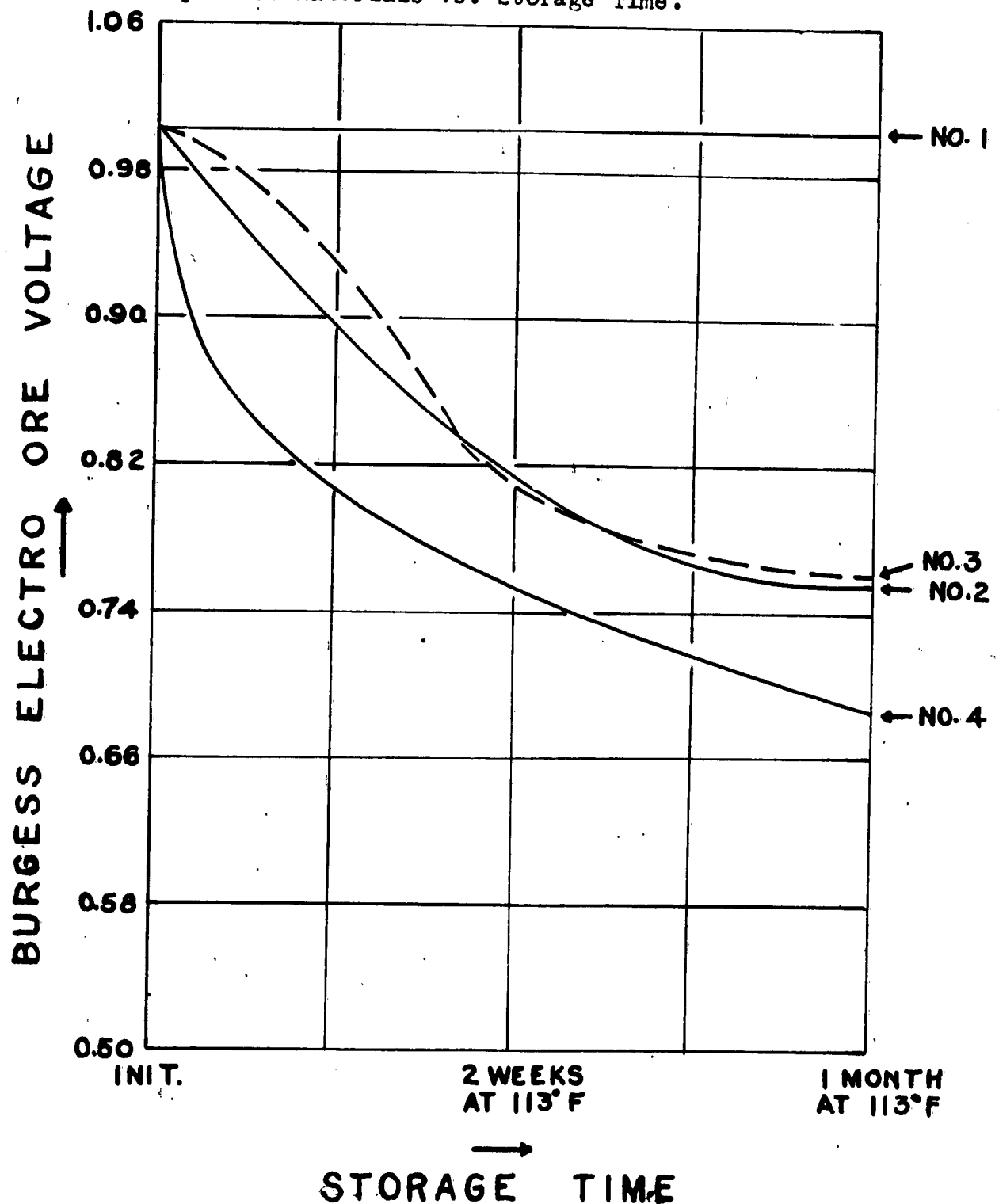


FIGURE 3 (Cont.)

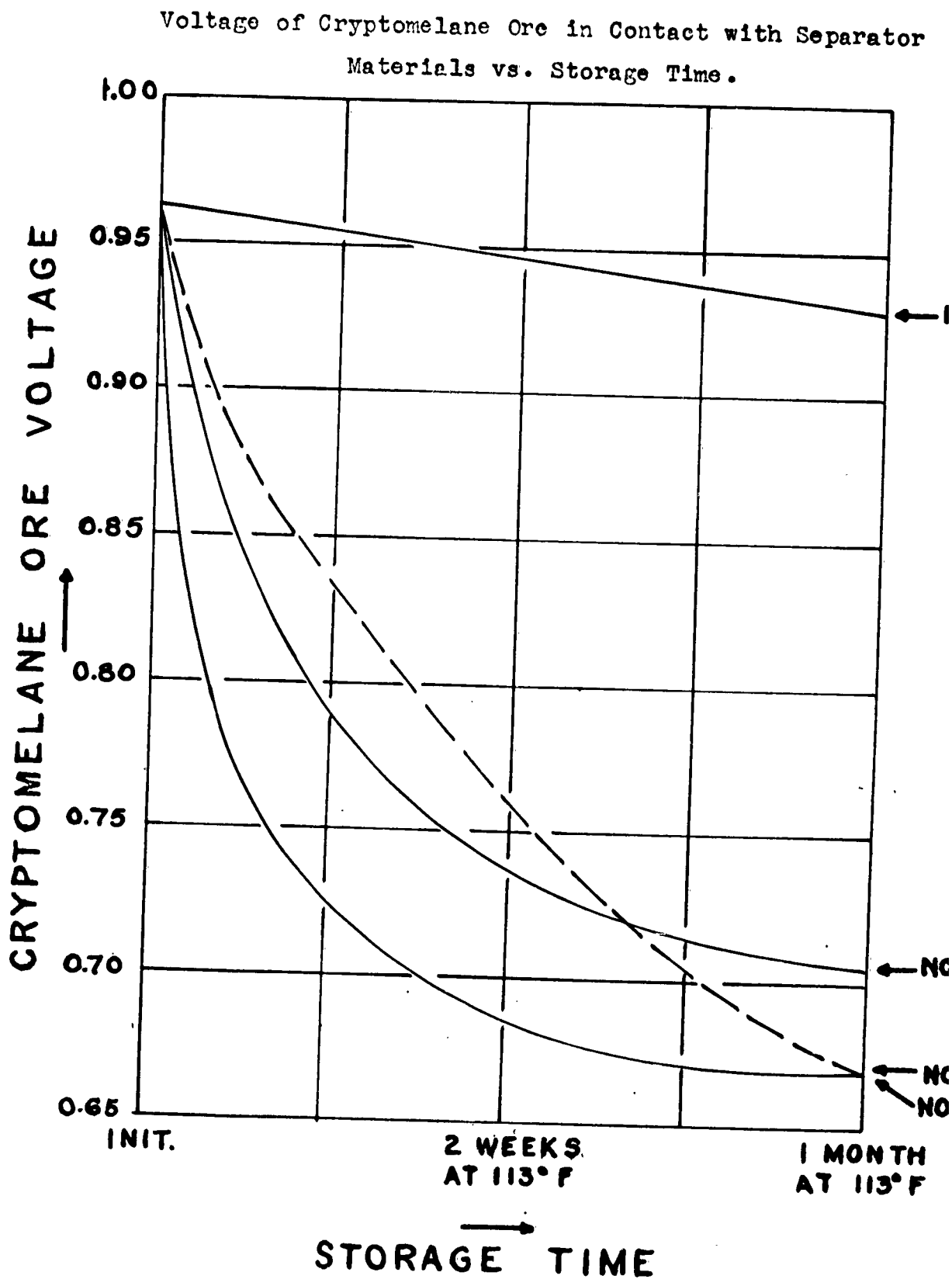


FIGURE 4 (Cont.)

REDUCTION IN AFRICAN ORE VOLTAGE WHEN STORED  
IN CONTACT WITH CONVENTIONAL SEPARATOR  
MATERIALS

Voltage of African Ore in Contact with Separator  
Materials vs. Storage Time After Six Months Storage

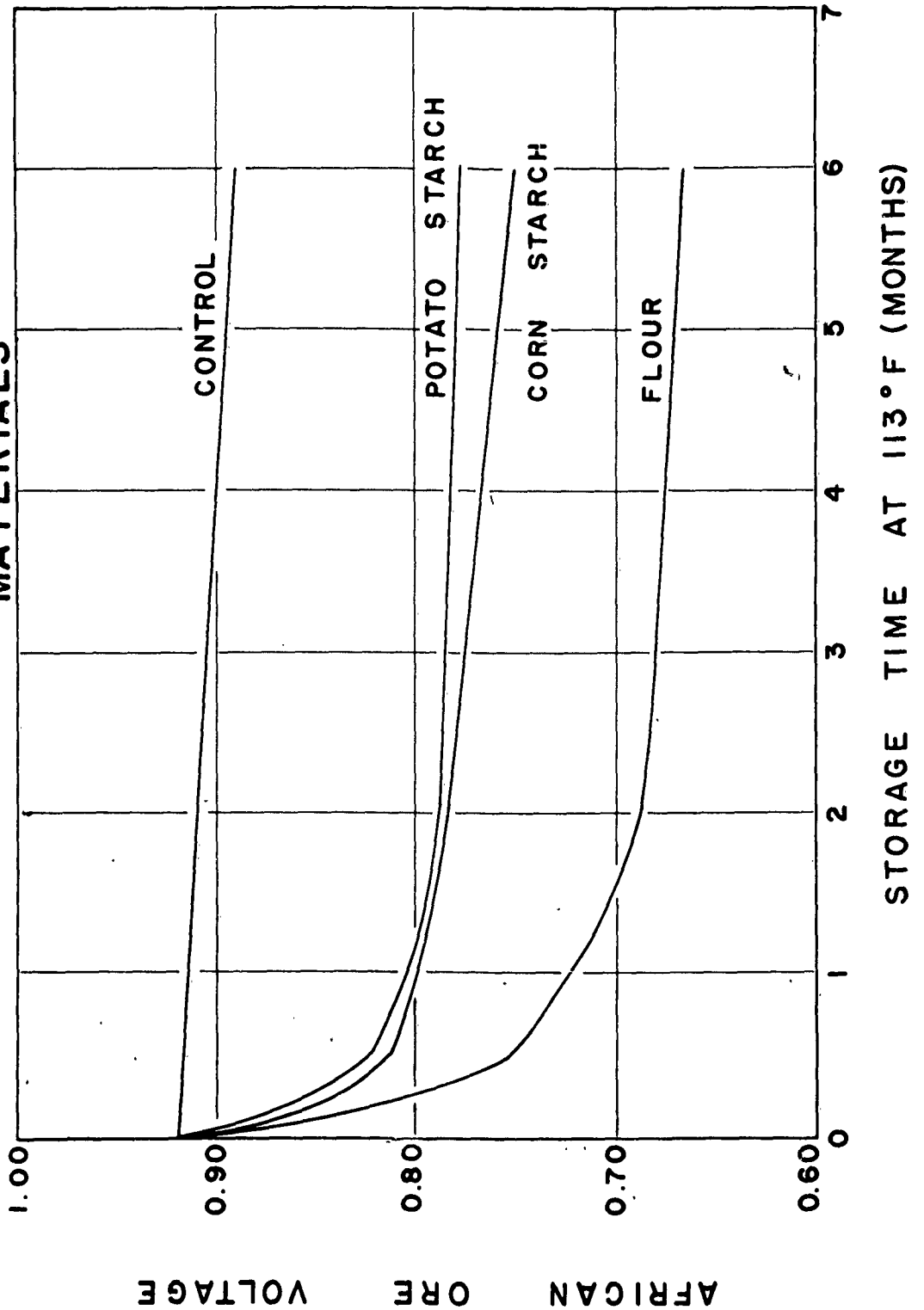


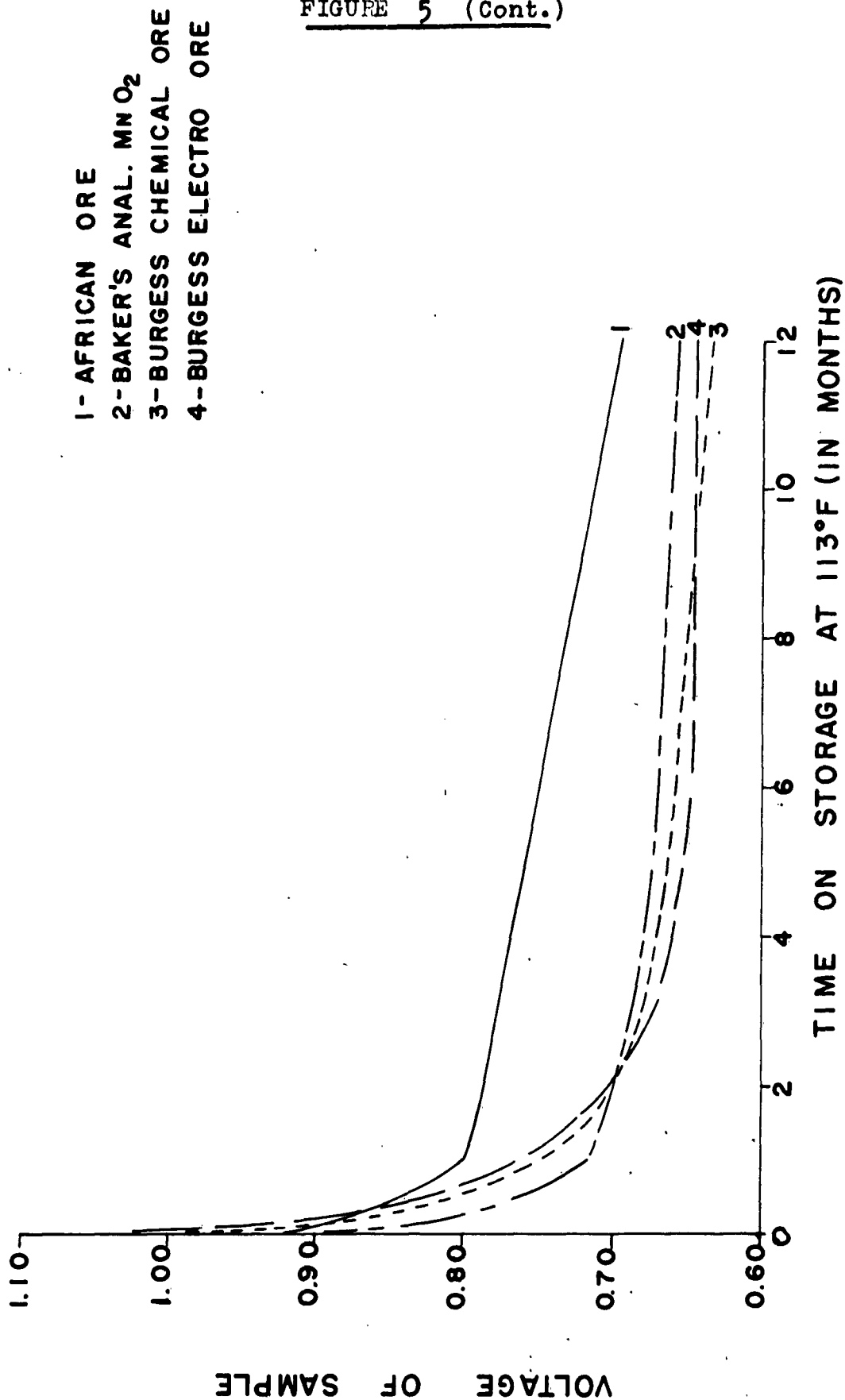
FIGURE 5

Comparison Of Voltage Reduction Caused By Common Separator Materials When Stored  
In Contact With Various Types Of Manganese Dioxide

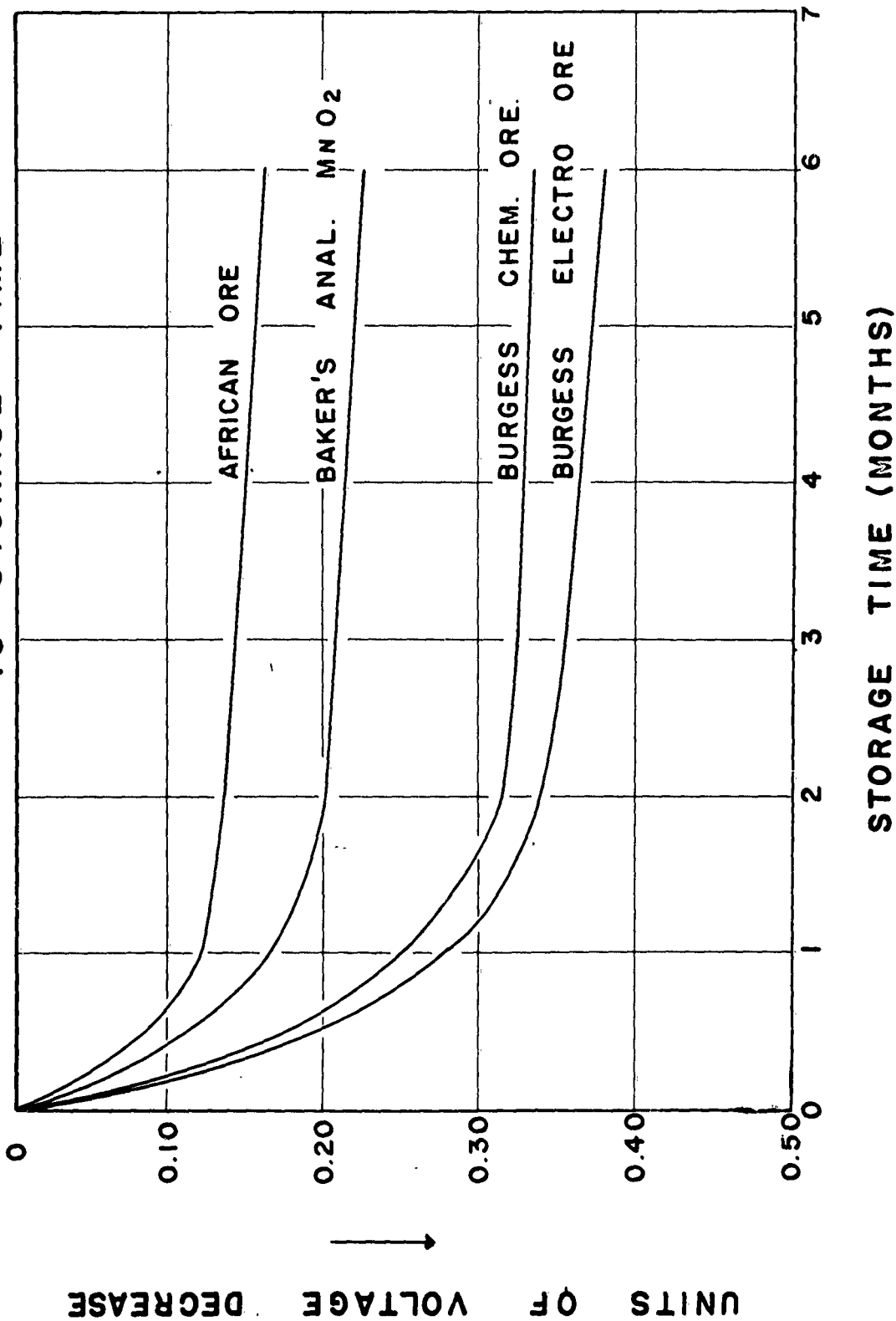
Mix Formulation		ore/black - 7/1 ("AA")						
Electrolyte Formulation		24.0% NH <sub>4</sub> Cl ; 22.5% ZnCl <sub>2</sub> ; 53.5% H <sub>2</sub> O						
Storage Conditions		Sealed glass jars - no zinc present						
Separator Thickness		0.438 inch						
Sample No.	Separator Material	Ore Tested	Voltage of sample after storage at 113° F.					Total Voltage Reduction
			Initial	1 month at 113°F	3 months at 113°F	6 months at 113°F	12 mos. at 113°F	
1A	Corn Starch	African Ore	0.920 v.	0.800 v.	0.780 v.	0.750 v.	0.702 v.	0.218 v.
2A	Potato Starch		0.920 v.	0.805 v.	0.785 v.	0.770 v.	0.722 v.	0.198 v.
3A	Flour		0.920 v.	0.724 v.	0.684 v.	0.666 v.	0.664 v.	0.256 v.
1B	Corn Starch	Baker's Anal. MnO <sub>2</sub>	0.895 v.	0.716 v.	0.688 v.	0.668 v.	0.654 v.	0.241 v.
2B	Potato Starch		0.895 v.	0.740 v.	0.694 v.	0.654 v.	0.658 v.	0.237 v.
3B	Flour		0.895 v.	0.672 v.	0.660 v.	0.650 v.	0.645 v.	0.250 v.
1C	Corn Starch	Burgess Chemical Ore	0.995 v.	0.744 v.	0.681 v.	0.659 v.	0.635 v.	0.360 v.
2C	Potato Starch		0.995 v.	0.750 v.	0.682 v.	0.654 v.	0.636 v.	0.359 v.
3C	Flour		0.995 v.	0.665 v.	0.643 v.	0.638 v.	0.622 v.	0.373 v.
1D	Corn Starch	Burgess Electro Ore	1.025 v.	0.755 v.	0.670 v.	0.647 v.	0.645 v.	0.380 v.
2D	Potato Starch		1.025 v.	0.762 v.	0.677 v.	0.647 v.	0.646 v.	0.379 v.
3D	Flour		1.025 v.	0.683 v.	0.653 v.	0.644 v.	0.625 v.	0.400 v.

FIGURE 5 (Cont.)

**EFFECT OF CORN STARCH ON THE VOLTAGE  
OF VARIOUS MANGANESE DIOXIDES**



# VOLTAGE DECREASE OF VARIOUS MANGANESE DIOXIDES STORED IN CONTACT WITH CORN STARCH VS STORAGE TIME



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FIGURE 6

Study To Determine If Starch Must Be In Contact With Manganese Dioxide In Order To Reduce The Voltage Of The Manganese Dioxide

Sample No.	Method of Testing	Voltage of sample after storage		
		Initial	1 mo. at 113°F.	Voltage Reduction
0	Control - Direct contact between starch and manganese dioxide (African ore)	0.920 v.	0.765 v.	0.155 v.
1	Starch separated from manganese dioxide by Dynel cloth and an electrolyte barrier	0.920 v.	0.784 v.	0.136 v.
2		0.920 v.	0.783 v.	0.137 v.
3		0.920 v.	0.807 v.	0.113 v.
4	Manganese dioxide in contact with electrolyte only.	0.920 v.	0.914 v.	0.006 v.

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FIGURE 7

Study Of The Effect Of Paste Of Varying Thicknesses On The  
Voltage Of Manganese Dioxide

Sample No.	Core Diameter	Paste Thickness	Ore Tested	Voltage of sample		Amount of reduction in voltage
				Initially	1 month at 113°F	
1	0.375 in.	0.093 in.	African Ore	0.920 v.	0.814 v.	0.106 v.
2	0.375 in.	0.156 in.	"	0.920 v.	0.794 v.	0.126 v.
3	0.375 in.	0.188 in.	"	0.920 v.	0.788 v.	0.132 v.
4	0.375 in.	0.281 in.	"	0.920 v.	0.780 v.	0.140 v.
5	0.375 in.	0.438 in.	"	0.920 v.	0.772 v.	0.148 v.
6	0.375 in.	0.531 in.	"	0.920 v.	0.766 v.	0.155 v.

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FIGURE 8

Effect Of Electrolyte pH On The Oxidation Of Flour Paste When  
Stored As A Paste In Contact With Manganese Dioxide At 113°F.

Electrolyte Formulation		24.0% NH <sub>4</sub> Cl; 22.5% ZnCl <sub>2</sub> ; 53.5% H <sub>2</sub> O (Composition by weight) NH <sub>4</sub> OH added to bring about pH rise			
Ore Tested		Burgess Electro ore mix as "AA" cores			
Sample No.	pH of Electrolyte	Separator Material	Voltage of sample		Voltage Reduction
			Initial	6 months	
6 0	3.80	Flour Paste	1.024 v.	0.652 v.	0.372 v.
60A	3.80	Control - Electrolyte only	1.062 v.	1.004 v.	0.058 v.
61	4.45	Flour Paste	0.988 v.	0.645 v.	0.343 v.
61A	4.45	Control	1.038 v.	1.002 v.	0.006 v.
62	4.70	Flour Paste	0.950 v.	0.640 v.	0.310 v.
62A	4.70	Control	0.996 v.	0.996 v.	0.000 v.
63	5.15	Flour Paste	0.875 v.	0.635 v.	0.240 v.
63A	5.15	Control	0.993 v.	0.961 v.	0.032 v.
64	5.40	Flour Paste	0.831 v.	0.628 v.	0.203 v.
64A	5.40	Control	0.935 v.	0.954 v.	-----
65	6.25	Flour Paste	0.853 v.	0.620 v.	0.233 v.
65A	6.25	Control	0.971 v.	0.965 v.	0.006 v.
66	7.20	Flour Paste	0.834 v.	0.561 v.	0.273 v.
66A	7.20	Control	0.922 v.	0.959 v.	-----
67	7.50	Flour Paste	0.685 v.	0.485 v.	0.200 v.
67A	7.50	Control	0.782 v.	0.836 v.	-----
6 8	7.90	Flour Paste	0.645 v.	0.472 v.	0.173 v.
68A	7.90	Control	0.692 v.	0.739 v.	-----

FIGURE 8 (Cont.)

EFFECT OF ELECTROLYTE PH ON THE VOLTAGE REDUCTION  
OF MANGANESE DIOXIDE AT 113°F

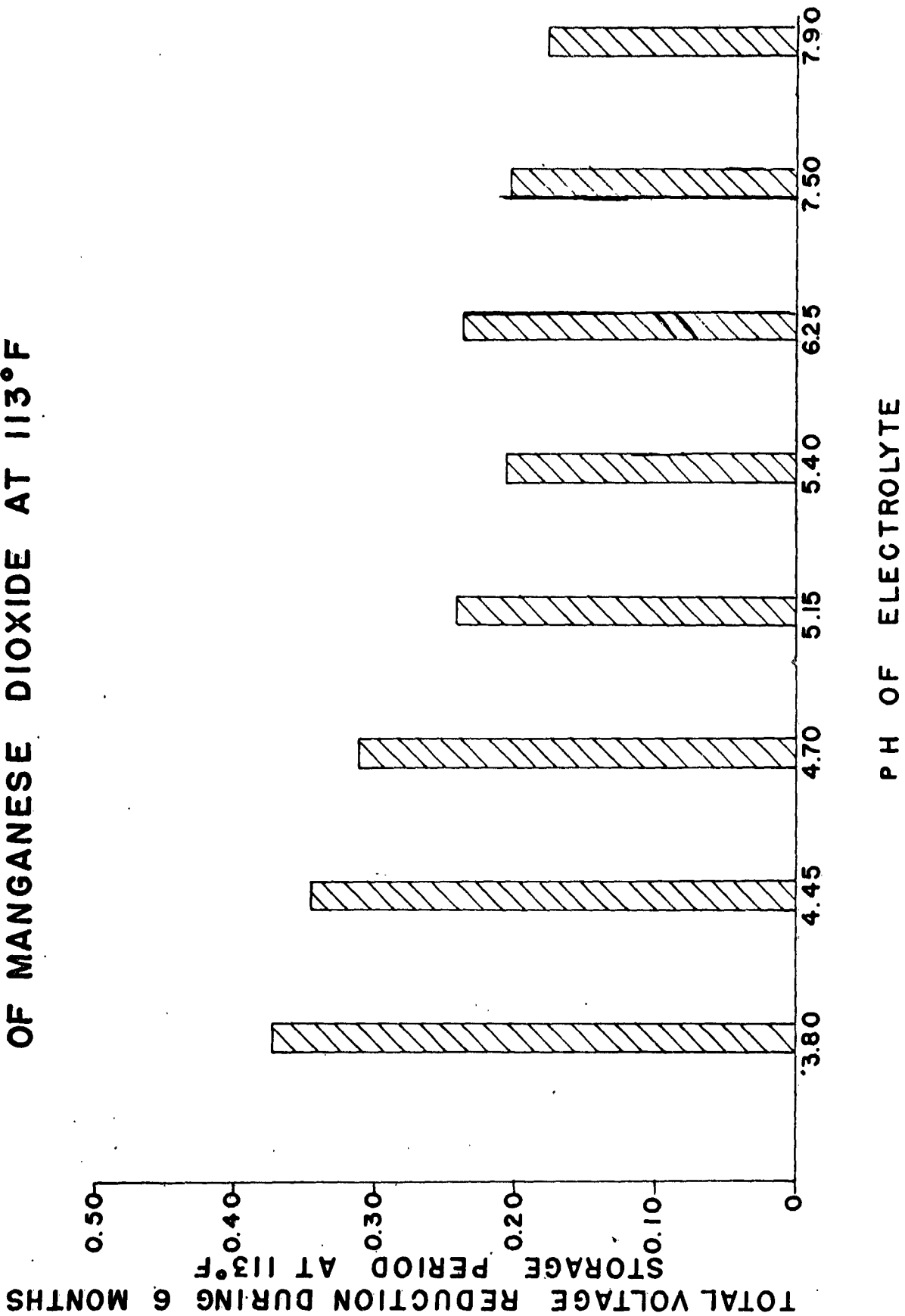


FIGURE 9

Effect of Separator Materials on the Voltage of Manganese Dioxide When Stored in Contact at 113°F.

Separator Materials	Voltage of sample		Voltage Reduction
	Initial	12 months	
Corn Starch	0.920 v.	0.702 v.	0.218 v.
Potato Starch	0.920 v.	0.722 v.	0.198 v.
Hubinger's O.K. Thin Boiling #20 Starch	0.920 v.	0.692 v.	0.228 v.
Hubinger's O.K. Waxy Sorghum Starch	0.920 v.	0.690 v.	0.230 v.
Staley Special Battery Starch	0.920 v.	0.692 v.	0.228 v.
P.F. Powder	0.920 v.	0.690 v.	0.230 v.
Ground Starch Sponge	0.920 v.	0.722 v.	0.198 v.
SD-12	0.920 v.	0.700 v.	0.220 v.
Northern Refined Flour	0.920 v.	0.708 v.	0.212 v.
Hallmark Powdered Potato Starch	0.920 v.	0.726 v.	0.194 v.
Hallmark SDSL	0.920 v.	0.712 v.	0.208 v.
Hallmark SDS	0.920 v.	0.703 v.	0.217 v.
Hallmark Powdered Wheat Starch	0.920 v.	0.710 v.	0.210 v.
Paygel P Wheat Starch	0.920 v.	0.708 v.	0.224 v.
STLM	0.920 v.	0.725 v.	0.195 v.
Shopal #8	0.920 v.	0.687 v.	0.233 v.
Hallmark Sago Base Starch	0.920 v.	0.715 v.	0.205 v.
Hygrade Maris	0.920 v.	0.713 v.	0.207 v.
Saliocca without wheat	0.920 v.	0.708 v.	0.212 v.
Saliocca	0.920 v.	0.672 v.	0.248 v.
Special Powder	0.920 v.	0.700 v.	0.220 v.
Hubinger's O.K. Powdered Starch	0.920 v.	0.703 v.	0.217 v.
B2455 P Wheat Starch	0.920 v.	0.711 v.	0.209 v.
Dry Flo	0.920 v.	0.732 v.	0.188 v.
Flogel #20	0.920 v.	0.728 v.	0.192 v.
Nalex #15	0.920 v.	0.715 v.	0.205 v.
Flogel #75	0.920 v.	0.722 v.	0.198 v.
Amioca #85	0.920 v.	0.725 v.	0.195 v.
Denatured Gluten	0.920 v.	0.759 v.	0.161 v.
Clear Flo L	0.920 v.	0.748 v.	0.172 v.
Santocel C	0.920 v.	0.823 v.	0.097 v.

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FIGURE 9 (cont.)

Separator Material	Voltage of sample		Voltage Reduction
	Initial	12 months	
Special Wheat Protein R2E-570	0.920 v.	0.777 v.	0.143 v.
Clear Flo H	0.920 v.	0.773 v.	0.147 v.
Puracol R12C - 425	0.920 v.	0.735 v.	0.185 v.
Protein #3323	0.920 v.	0.760 v.	0.160 v.
Devitalized Wheat Gluton	0.920 v.	0.770 v.	0.150 v.
Triticote #87	0.920 v.	0.744 v.	0.176 v.
Special Wheat Protein R2E-1301	0.920 v.	0.750 v.	0.170 v.
Flour	0.920 v.	0.664 v.	0.256 v.
Soya Flour	0.920 v.	0.600 v.	0.320 v.
Melamine Starch	0.920 v.	0.653 v.	0.267 v.
Formalin-Urea Starch	0.920 v.	0.650 v.	0.270 v.
Formalin Starch	0.920 v.	0.653 v.	0.267 v.

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FIGURE 9 (cont.)

Sample No.	Separator Material Tested	Voltage of sample after storage				
		Init.	1 mo.	3 mos.	6 mos.	9 mos.
23	9-D-138 Modified Tapiocca	0.920	0.768	0.760	0.751	0.731
24	Hallmark - Sago Base St. (Stein-Hall Co.)	0.920	0.792	0.772	0.755	0.731
28	Hubinger's O.K. Powdered Starch	0.920	0.790	0.772	0.754	0.723
29	B-2455 Wheat Starch (General Mills inc.)	0.920	0.791	0.772	0.759	0.725
30	Starch xR-32 (Corn Products Co.)	0.920	0.812	0.795	0.774	
31	SH-11 (Stein-Hall Co.)	0.920	0.836	0.807	0.778	
32	Clear Flo L (National Starch Co.)	0.920	0.844	0.827	0.815	
33	Clear Flo H (National Starch Co.)	0.920	0.860	0.847	0.830	
34	Dry Flo (National Starch Co.)	0.920	0.822	0.796	0.758	
35	ARD - 162 (American Maize Products)	0.920	0.833	0.814	0.786	
36	Pearl Corn Starch (American Maize Products)	0.920	0.832	0.809	0.786	
37	Gelex (American Maize Products)	0.920	0.828	0.816	0.802	
38	W-11 Starch (American Maize Products)	0.920	0.833	0.808	0.780	
39	Flogel 75 (National Starch Co.)	0.920	0.820	0.803	0.779	
40	Flogel 20 National Starch Co.)	0.920	0.825	0.800	0.780	
41	Nalex 15 (National Starch Co.)	0.920	0.816	0.795	0.768	

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FIGURE 9 (cont.)

Sample No.	Separator Material Tested	Voltage of sample after storage				
		Init.	1 mo.	3 mos.	6 mos.	9 mos.
42	Globe Pearl Starch (Corn Products Co.)	0.920	0.824	0.808	0.784	
43	Amigold Yellow Corn Flour (Corn Products Co.)	0.920	0.823	0.807	0.788	
44	Carboxy Methyl Starch	0.920	0.789	0.770	0.765	
45	APCG (Stein-Hall Co.)	0.920	0.810	0.804	0.798	
46	Karaya Gum (Stein-Hall Co.)	0.920	0.866	0.867	0.857	
47	Tragacanth Gum (Stein-Hall Co.)	0.920	0.810	0.792	0.773	
48	RST Starch (A.E. Staley Co.)	0.920	0.843	0.813	0.787	
49	1.0 Pa3 Starch (A.E. Staley Co.)	0.920	0.843	0.813	0.785	
50	0.5 Pa4 Starch (A.E. Staley Co.)	0.920	0.846	0.813	0.783	
51	Argo Brand Zein (Corn Products Co.)	0.920	0.855	0.845	0.830	
52	A-21-S Wheat Starch (General Mills Inc.)	0.920	0.805	0.795		
53	A-22 Purified Wheat Starch (General Mills Inc.)	0.920	0.806	0.799		
54	Corn Steep Liquor (A.E. Staley Co.)	0.920	0.796	0.790	0.786	
55	Special Nutrient #22 (A.E. Staley Co.)	0.920	0.798	0.793	0.787	
56	Special Nutrient #165 (A.E. Staley Co.)	0.920	0.800	0.796	0.795	

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FIGURE 10

Study of Separator Materials Which Have Shown Promise During  
Storage at 160° F.

Mix Formulation	Ore/Black - 7/1				
Electrolyte Formulation	24.0% NH <sub>4</sub> Cl ; 22.5% ZnCl <sub>2</sub> ; 53.5% H <sub>2</sub> O (Composition by weight)				
Storage Conditions	Sealed glass jars - thus eliminating the presence of zinc - Samples stored at 160°F.				
Separator Thickness	0.438 inch				
Ore Tested	African ore				
Sample No.	Separator Material Tested	Voltage of sample after storage			
		Init.	2 weeks	4 weeks	6 weeks
0	Control - Electrolyte	0.901 v.	0.851 v.	0.847 v.	0.837 v.
1	Corn Starch	0.901 v.	0.685 v.	No gel structure at 4 weeks	
2	Staley's Special Battery Starch (A.E. Staley Co.)	0.901 v.	0.725 v.	No gel structure at 4 weeks	
3	P. F. Powder (American Maize Prod.)	0.901 v.	0.718 v.	No gel structure at 4 weeks	
4	SD-12 (Stein-Hall Co.)	0.901 v.	0.714 v.	No gel structure at 4 weeks	
5	Staley's Battery Starch (A.E. Staley Co.)	0.901 v.	0.717 v.	0.669 v.	0.613 v.
6	Melamine Starch	0.901 v.	0.672 v.	0.659 v.	0.642 v.
7	Paygel P - wheat Starch (General Mills Inc.)	0.901 v.	0.713 v.	No gel structure at 4 weeks	
8	Shopal #8 (Stein-Hall Co.)	0.901 v.	0.781 v.	No gel Structure at 4 weeks	
9	Hallmark Sago Base Starch (Stein-Hall Co.)	0.901 v.	0.735 v.	No gel structure at 4 weeks	
10	Saliocca without wheat	0.901 v.	0.718 v.	No gel structure at 4 weeks	

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FIGURE 10 (cont.)

Sample No.	Separator Material Tested	Voltage of sample after storage			
		Initial	2 weeks	4 weeks	6 weeks
11	Saliocca with wheat	0.901 v.	0.717 v.	No gel structure at 4 weeks	
12	Hubinger's O.K. Powdered Starch	0.901 v.	0.726 v.	No gel structure at 4 weeks	
13	Globe Pearl Starch (Corn Products Co.)	0.901 v.	0.717 v.	0.665 v.	No gel left
14	Flogel #20 (National Starch Co.)	0.901 v.	0.714 v.	No gel structure at 4 weeks	
15	Flogel #75 (National Starch Co.)	0.901 v.	0.713 v.	No gel structure at 4 weeks	
16	ARD-162 (American Maize Prod.)	0.901 v.	0.720 v.	No gel structure at 4 weeks	
17	Pearl Corn Starch (American Maize Prod.)	0.901 v.	0.716 v.	No gel structure at 4 weeks	
18	Polyvinyl Alcohol - high viscosity	0.920 v.	0.816 v.	0.805 v.	0.806 v.
19	Carboxy Methyl Cellulose low viscosity	0.920 v.	0.816 v.	0.810 v.	No gel left
20	Karaya Gum (Stein-Hall Co.)	0.920 v.	0.839 v.	0.823 v.	No gel left
21	Tragacanth Gum (Stein-Hall Co.)	0.920 v.	0.716 v.	0.700 v.	No gel left
22	RST Starch (A.E. Staley Co.)	0.920 v.	0.755 v.	0.661 v.	0.658 v.
23	1.0 Pa3 Starch (A.E. Staley Co.)	0.920 v.	0.753 v.	0.660 v.	0.652 v.
24	0.5 Pa4 Starch (A.E. Staley Co.)	0.920 v.	0.753 v.	0.659 v.	0.650 v.
25	Guar Gum (General Mills Inc.)	0.920 v.	0.744 v.	No gel structure at 4 weeks	
26	Argo Brand Corn (Corn Products Co.)	0.920 v.	0.836 v.	0.806 v.	0.764 v.

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FIGURE 10(cont.)

Sample No.	Separator Material Tested	Voltage of sample after storage			
		Initial	2 weeks	4 weeks	6 weeks
27	Corn Steep Liquor (A.E.Staley Co.)	0.920 v.	0.795 v.	0.765 v.	0.716 v.
28	Special Nutrient #22 (A.E.Staley Co.)	0.920 v.	0.804 v.	0.775 v.	0.764 v.
29	Special Nutrient #165 (A.E.Staley Co.)	0.920 v.	0.800 v.	0.771 v.	0.764 v.
30	A-21-S wheat Starch (General Mills Inc.)	0.901 v.	0.720 v.	0.645 v.	0.656 v.
31	A22 Purified Wheat Starch (General Mills)	0.901 v.	0.717 v.	0.653 v.	0.636 v.
32	B2455 Wheat Starch (General Mills Inc.)	0.901 v.	0.710 v.	0.650 v.	0.640 v.

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FIGURE 10 (con't)

Sample No.	Separator Material Tested	Ore Tested	Voltage of sample after storage			
			Initial	2 wks. at 160°F	4 wks. at 160°F	6 wks. at 160°F
32A	Nalex #15 (National Starch Company)	African ore	0.901 v.	No gel structure at 2 weeks		
33A	Flogel #75 (National Starch Company)	African ore	0.901 v.	0.713 v.	No gel structure at 4 weeks	
34A	Waxy Maize	African ore	0.901 v.	No gel structure at 2 weeks		
35A	W-11 (Amer. Maize Products)	African ore	0.901 v.	No gel structure at 2 weeks		
36A	Gelex (Amer. Maize Products)	African ore	0.901 v.	No gel structure at 2 weeks		
37A	ARD-162 (Amer. Maize Products)	African ore	0.901 v.	0.720 v.	No gel structure at 4 weeks	
38A	Pearl Corn Starch	African ore	0.901 v.	0.716 v.	No gel structure at 4 weeks	
39A	Control (Electrolyte only)	Baker's Anal. MnO <sub>2</sub>	0.874 v.	0.855 v.	0.849 v.	0.831 v.
40A	Corn Starch	Baker's Anal. MnO <sub>2</sub>	0.874 v.	0.645 v.	0.611 v.	0.600 v.
41A	Potato Starch	Baker's Anal. MnO <sub>2</sub>	0.874 v.	0.647 v.	0.632 v.	0.520 v.
42A	Flour	Baker's Anal. MnO <sub>2</sub>	0.874 v.	No gel structure at 2 weeks		

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FIGURE 10(con't)

Sample No.	Separator Material Tested	Ore Tested	Voltage of sample after storage			
			Initial	2 wks. at 160°F	4 wks. at 160°F	6 wks. at 160°F
43A	Control (Electrolyte only)	Burgess Chem.	1.010 v.	0.943 v.	0.927 v.	0.898 v.
44A	Corn Starch	Burgess Chem.	1.010 v.	0.632 v.	No gel structure at 4 weeks	
45A	Potato Starch	Burgess Chem.	1.010 v.	No gel structure at 2 weeks		
46A	Flour	Burgess Chem.	1.010 v.	No gel structure at 2 weeks		
47A	Control (Electrolyte only)	Burgess Electro	1.055 v.	1.001 v.	0.961 v.	0.943v.
48A	Corn Starch	Burgess Electro	1.055 v.	0.646 v.	No gel structure at 4 weeks	
49A	Potato Starch	Burgess Electro	1.055 v.	No gel structure at 2 weeks		
50A	Flour	Burgess Electro	1.055 v.	No gel structure at 2 weeks		
51A	Control (Electrolyte only)	Crypt. (Lt. Hyd.) leached in ZnCl <sub>2</sub> solution	0.944 v.	0.837 v.	0.814 v.	0.801 v.
52A	Corn Starch		0.944 v.	0.640 v.	0.612 v.	0.535 v.
53A	Potato Starch		0.944 v.	0.632 v.	No gel structure at 4 weeks	
54A	Flour		0.944 v.	0.632 v.	No gel structure at 4 weeks	

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## **PART IV**

# **PAPER COATED SEPARATORS**

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#### Part IV - Paper Coated Separators

Many studies were conducted in this project to determine what effect a conventional separator material has on the voltage reduction of manganese dioxide. Considerable data have been collected to prove that a conventional separator substantially reduces the voltage of a manganese dioxide ore. Of the various types of materials tested, proteins, glutens and most gum type materials caused the smaller voltage reduction.

However, as this class of material cannot be handled in the conventional manner (due to the lack of gel formation), considerable effort was put on the study and use of paper-coated separators. As this study has many different and unique features it is reported here separately in order to clearly establish this particular work.

The preliminary step in this new phase of work in separators was to order a paper coating machine. A paper gumming machine which can be adapted for coating paper was obtained from the New Jersey Machine Corporation of Hoboken, New Jersey. The machine did not arrive until May 7, 1953 which caused considerable delay in the accomplishment of this work. In the meantime, background work was started in regard to this investigation by fabricating and testing cells made from Eveready methyl cellulose paper as a separator.

With the arrival of the machine, preliminary trial runs were made in order to establish sound procedures in regard to coating the paper with the separator material. A roll of Nibroc Kraft Water Paper was obtained on which to apply the various materials. It was found that two coatings applied a film slightly over .001" giving a combined paper thickness of .004".

As soon as familiarity with the coating machine was achieved, paper was coated using Carboxy Methyl Cellulose Gums, Polyvinyl alcohol and various other gum products. The materials were prepared for coating by dissolving in distilled water in percentages ranging from 1% to 10% by weight until a fairly fluid solution was prepared. The solutions were desired in this fluid state to allow even flow and thickness when applied to the paper. The paper when dried was then cut into squares  $3\frac{1}{4}$ " x 4", wrapped on a hand mandrel, the bottom folded over, and lined into the zinc cans for fabrication into dry cells. The paper was inserted into the cans by the use of liner mandrels approximately 1-7/64" diameter.

Certain problems were encountered initially in regard to the fabrication of paper lined cells. Basically they are as follows:

- (a) Type of can construction and seal to be used.
- (b) Method of tamping mix and the addition of the depolarizer to the paper-lined cans.
- (c) Proper amount of mix weight desirable in this type of cell.

(d) Proper degree of mix wetness satisfactory for storage at elevated temperatures.

In regard to the problem of can construction, it was finally decided that a standard leakproof assembly would provide the most optimum conditions for this type of work. This consists of a flat-bottom zinc leakproof can with a high resistant polystyrene cap and a polyethylene gasket as a seal. The gasket was stamped out of polyethylene sheets approximately  $1\frac{1}{2}$ " in diameter. Several new tools were required in order to insure proper specifications for the leakproof cell. These tools consisting of a tamping rod, pencil guides and liner rods were made of a hard rubber composition.

After several experimental runs it was decided that the best procedure was to tamp a mix slug of from sixty to sixty-five grams,  $2\frac{1}{4}$ " long by 1.029" in diameter. These slugs were then placed in the previously lined cans and retamped with a tamping rod which is 1.113" in diameter. An adjusted stop on the arbor press regulated the final core height at  $1-5/8$ ".

The carbon rod was inserted into the depolarizer with the use of a pencil guide which measures 1.131" in diameter. Finally, the excess paper was folded down and pressed over the depolarizer and around the carbon rods by exerting slight pressure on the pencil guide. The small compression brings contact between the depolarizer, separator and zinc can by squeezing electrolyte out of the mix, and wetting the paper separator which results in proper conductance within the cell. Complete specifications for the various tools and materials used are reported in Figure A along with a chart showing the percentage of mix ingredients for an average mix.

The electrolyte that has been used in all testing to date is standard battery electrolyte (zinc chloride, ammonium chloride and water) with 0.25% mercuric chloride added.

The most difficult problem to overcome in the construction of paper lined cells concerns the proper degree of mix wetness. Considerable emphasis must be placed on this condition because of its extreme importance toward dry cell efficiency especially at elevated temperatures. To understand what occurs over a varied series of mix wetnesses, cells were constructed using mixes that ranged from extreme dryness to extra wetness. The table in Figure #1 shows capacities received from these cells. The first batch of cells in the series gave no results at two weeks at  $160^{\circ}\text{F}$ . because of their extreme dryness. As the mix wetness increases, it can be noted that capacities increase, but this is accordingly accompanied by an increase in corrosion of the cells. Subsequent results have shown that the medium wet mix (approximate average regular dry mix) is the best mix condition for paper lined cells.

Capacities obtained to date on cells fabricated are reported in Figure #2. Several exceptional facts are evident from this data. Eveready methyl cellulose paper has been outstanding as a paper separator giving capacities that far exceed the conditions specified in the contract. The other materials

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tested have not performed satisfactorily. At elevated temperatures capacities are completely gone. This most probably is attributable to the fact that these materials completely break down at these high temperatures thus destroying the efficiency of the cell.

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Conclusions

1. Most water soluble materials that show promise as separator materials can be readily coated for paper-lined cells.
2. Close regulation of the mix wetness must be maintained in order to achieve the optimum conditions of capacity and yet overcome the problem of corrosion.
3. Except for Eveready paper, the materials tested to date have completely broken down at elevated temperatures thus becoming useless in the cell as a separator.
4. Eveready methyl cellulose paper has shown exceptional merit as a separator material and cells made with this paper have given capacities far exceeding the specifications in the contract for temperatures of 130°F. - 50% R.H. and 160°F. - 50% R.H.

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TABLES AND RESULTS

PART IV

PAPER COATED SEPARATORS

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FIGURE A

Specifications of Various Tools and Materials Used in  
Producing Paper Lined "D" Cells (Paper Coated Separators)

Tools @ Materials	Composition	Diameter	Length	Weight	Thickness
Coated paper	Paper-Nibro Craft Water	-----	3 $\frac{1}{4}$ " x 4"	0.60 gm.	.004"
Liner mandrels	Hard rubber	1.062"	6 $\frac{3}{4}$ "	-----	-----
Flat bottom leakproof Can	Zinc	1.250"	2.250"	14 gms.	wall .016"
Core mold	Stilite plated steel	1.058"	4 $\frac{1}{2}$ "	-----	wall .125"
Tamping rod (mold)	Stilite plated steel	1.045"	5 $\frac{1}{2}$ "	-----	-----
Mix slug	Depolarizer material	1.029 (approx)	2 $\frac{1}{4}$ "	60-65 gms.	-----
Final core slug diminsion	Depolarizer material	1.210" (approx)	1 $\frac{5}{8}$ "	60-65 gms.	-----
Tamping rod (can)	Hard rubber	1.113"	4 $\frac{1}{2}$ "	-----	-----
Pencil guide	Lucite	1.131"	1 $\frac{1}{2}$ "	-----	hole dia .350"
Polyethylene gasket	Polyethylene	1 $\frac{1}{2}$ "	-----	0.20 gms	.005"

Percentage of Mix Ingredients  
(average mix)

African Ore	64.4 %
Carbon Black	9.2 %
Sal (NH <sub>4</sub> Cl)	9.2 %
Standard Electrolyte (0.25% HgCl <sub>2</sub> )	17.2 %

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FIGURE 1

Construction of Paper Lined Cells ("D" Size) in the Varied  
Wetness Series

Lot No.	Mix Formulation	Mix Wetness	Separator	Subseal	Seal
D-1280	100% African Ore 7/1 ore to black Inhibitor present (.25% $\text{HgCl}_2$ )	Extreme dry	Eveready Methyl Cellulose Paper	Poly- ethylene gasket	Poly- Styrene cap
D-1283	100% African Ore 7/1 ore to black Inhibitor present (.25% $\text{HgCl}_2$ )	Regular "D" cell wetness	Eveready Methyl Cellulose Paper	Poly- ethylene gasket	Poly- Styrene cap
D-1282	100% African Ore 7/1 ore to black Inhibitor present (.25% $\text{HgCl}_2$ )	Medium wetness	Eveready Methyl Cellulose Paper	Poly- ethylene gasket	Poly- Styrene cap
D-1281	100% African Ore 7/1 ore to black Inhibitor present (.25% $\text{HgCl}_2$ )	Extreme wetness	Eveready Methyl Cellulose Paper	Poly- ethylene gasket	Poly- Styrene cap

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FIGURE 1A

Capacity of Paper Lined Cells ("D" Size ) in the Varied  
Wetness Series

Lot No.	Capacity		Results			
	BA 30 (days)		BA 8 (hours)		BA 408/U (hours)	
	Initial	2 weeks at 160°F	Initial	2 weeks at 160°F	Initial	2 weeks at 160°F
D-1280	14.9 days	Cells no good	208 hours	Cells no good	25.2 hours	Cells no good
D-1283	18.1 days	14.1 days	269.2 hours	203.3 hours	28.3 hours	16.8 hours
D-1282	19.6 days	15.3 days	284 hours	202.6 hours	28.7 hours	18.4 hours
D-1281	21.5 days	15.6 days	292.8 hours	242.3 hours	32.8 hours	22.8 hours

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FIGURE 2

Paper Lined "D" Cells For Storage (Construction).

Storage Time Before Initial Testing At 70° F.		2 weeks at 70° F. - 50% R.H.		
Storage Time For Cells Stored (Tested at 70° F.)		3 months at 70°F. - 50% R.H. 3 months at 113°F - 95% R.H. 3 months at 130°F - 50% R.H. 2 weeks at 160°F - 50% R.H.		
Lot No.	Mix Formulation	Separator	Subseal	Seal
D1003	100% African Ore 7/1 - ore/ black 0.25% HgCl <sub>2</sub> -(inhib)	Eveready Methyl Cellulose Paper	Poly-ethylene gasket	Poly-styrene cap
D1284	100% African Ore 7/1 - ore/black 0.25% HgCl <sub>2</sub> -(inhib)	Eveready Methyl Cellulose Paper	Poly-ethylene gasket	Poly-styrene cap
D1112	100% Western Elect. 7/1 - ore/black 0.25% HgCl <sub>2</sub> -(inhib)	Eveready Methyl Cellulose Paper	Poly-ethylene gasket	Poly-styrene cap
D1172	30% African Ore 70% Western Electro 7/1 ore/black 0.25% HgCl <sub>2</sub> -(inhib)	Eveready Methyl Cellulose Paper	Poly-ethylene gasket	Poly-styrene cap
D1481	100% African Ore 7/1 ore/black 0.25% HgCl <sub>2</sub> -(inhib)	Carboxy methyl Cellulose Paper (low viscosity)	Poly-ethylene gasket	Poly-styrene cap
D2294	100% African Ore 7/1 ore/black 0.25% HgCl <sub>2</sub> -(inhib)	Carboxy methyl Cellulose Paper (medium viscosity)	Poly-ethylene gasket	Poly-styrene cap
D1793	100% African Ore 7/1 ore/black 0.25% HgCl <sub>2</sub> -(inhib)	Carboxy methyl Cellulose Paper (high viscosity)	Poly-ethylene gasket	Poly-styrene cap
D2309	100% African Ore 7/1 ore/black 0.25% HgCl <sub>2</sub> -(inhib)	Polyvinyl alcohol "Elvanol" (low viscosity)	Poly-ethylene gasket	Poly-styrene cap

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FIGURE 2 (Cont.)

Lot No.	Mix Formulation	Separator	Subseal	Seal
D2337	100% African Ore 7/1 ore/black 0.25% HgCl <sub>2</sub> -(inhib.)	Polyvinyl alcohol "Elvanol" (medium viscosity)	Poly-ethylene gasket	Poly-styrene cap
D2390	100% African Ore 7/1 ore/black 0.25% HgCl <sub>2</sub> -(inhib.)	Arabic Gum "Acacia"	Poly-ethylene gasket	Poly-styrene cap
D2401	100% African Ore 7/1 ore/black 0.25% HgCl <sub>2</sub> -(inhib.)	Locust Bean Gum "Italian"	Poly-ethylene gasket	Poly-styrene cap
D2580	100% African Ore 7/1 ore/black 0.25% HgCl <sub>2</sub> -(inhib.)	Swifts Colloid Gum (No. 1 )	Poly-ethylene gasket	Poly-styrene cap
D2579	100% African Ore 7/1 ore/black 0.25% HgCl <sub>2</sub> -(inhib.)	Gelatine Gum	Poly-ethylene gasket	Poly-styrene cap

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FIGURE 2A

Paper Lined "D" Cells For Storage (Capacity Results)

Book No.	Specified Test	TEST RESULTS				
		Storage Temperature				
		70° F.		113° F.	130° F.	160° F.
		Initial	3 months	3 months	3 months	2 weeks
D1003	BA 30 (days)	20.7	18.3	18.9	17.9	15.9
	BA 8 (hours)	283	274	251	241	263
	BA 408 (hours)	27.6	32.4	26.2	26.6	25.4
D1284	BA 30 (days)	21.0	18.5	17.9	17.0	17.7
	BA 8 (hours)	298	288	288	249	280
	BA 408 (hours)	32.8	33.2	28.9	30.4	28.3
D1112	BA 30 (days)	34.5	21.6	21.3	22.3	19.5
	BA 8 (hours)	510	430	383	486	458
	BA 408 (hours)	61.7	67.7	65.5	63.5	44.0
D1172	BA 30 (days)	33.3	28.6	32.1	31.6	19.2
	BA 8 (hours)	458	400	447	419	336
	BA 408 (hours)	57.9	59.4	60.7	57.1	40.0
D1481	BA 30 (days)	15.0	14.5	12.2	10.2	Cells no good
	BA 8 (hours)	254	245	205	124	Cells no good
	BA 408 (hours)	26.9	19.9	14.7	14.3	Cells no good

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FIGURE 2A (Cont.)

Book No.	Specified Test	TEST RESULTS				
		Storage Temperature				
		70° F.		113° F.	130° F.	160° F.
		Initial	3 months	3 months	3 months	2 weeks
D2294	BA 30 (days)	14.0				Cells no good
	BA 8 (hours)	269				52.5
	BA 408 (hours)	23.7				Cells no good
D1793	BA 30 (days)	15.1	11.1	3.0	2.2	Cells no good
	BA 8 (hours)	240	169	125	90.1	16.0
	BA 408 (hours)	26.9	22.3	17.3	Cells no good	Cells no good
D2309	BA 30 (days)	16.6				Cells no good
	BA 8 (hours)	283				53
	BA 408 (hours)	28.6				14.7
D2337	BA 30 (days)	15.5				Cells no Good
	BA 8 (hours)	275				99
	BA 408 (hours)	26.6				Cells no good
D2390	BA 30 (days)	12.7				Cells no good
	BA 8 (hours)	241				56
	BA 408 (hours)	26.2				Cells no good

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FIGURE 2A (Cont.)

TEST RESULTS						
Book No.	Specified Test	Storage Temperature				
		70° F.		113° F.	130° F.	160° F.
		Initial	3 months	3 months	3 months	2 weeks
D2401	BA 30 (days)	9.3				Cells no good
	BA 8 (hours)	255				Cells no good
	BA 408 (hours)	26.9				Cells no good
D2580	BA 30 (days)	6.8				Cells no good
	BA 8 (Hours)	227				Cells no good
	BA 408 (hours)	16.4				Cells no good
D2579	BA 30 (days)	10.7				Cells no good
	BA 8 (hours)	224				Cells no good
	BA 408 (hours)	25.1				Cells no good

-\*\*\* Blank spaces in this data are due to incomplete  
returns of capacity results.

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**PART V**

**POLARIZATION STUDY  
CORROSION INHIBITORS**

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## Part V - Polarization Studies

### A. Polarization Inhibitors

A corrosion inhibitor in order to be acceptable for use in a dry cell must prevent corrosion of the zinc anode and function without interfering with the electrochemical reactions of the cell. A material which produces a high anodic polarization must not cause anodic passivity of the zinc. The inhibitor should be capable of inducing an appreciable degree of cathodic polarization over the whole metal surface to provide an effective corrosion barrier. The corrosion barrier is defined as the algebraic difference between the cathodic and anodic voltages.

Extensive experimental work was done to evaluate inhibitors suitable for the high temperature conditions imposed by this contract. Anodic and cathodic polarization studies were made after various periods of storage at 113°F, 130°F and 160°F.

The polarization apparatus and methods employed for the study are described in Part I (Equipment - Procedure) and a diagram of the operations is shown in Figure #1 of that section.

Use of this apparatus permitted the investigation of anodic inhibitors apart from the complicated reactions occurring in the cathode area.

These polarization studies were divided into two groups: (1) studies in which a current density equivalent to that of the BA-30 drain (4.33 ma/cm<sup>2</sup>) is imposed on the electrode immediately and held constant while the voltage changes are recorded with time, and (2) studies in which extremely light current densities are imposed initially and increased by small increments during the run. In the second instance, time is allowed for voltage (or polarization) equilibrium to develop before the voltage readings are recorded. Voltage is then plotted against current density. The change of cathodic polarization with current density is measured alternately with that of the anodic polarization by using two identical zinc electrodes in conjunction with a calomel reference electrode.

Some forty-two inhibitors have been analyzed on both these tests. The results of six representative samples for anodic polarization of zinc are tabulated and shown graphically in Figure #1. The majority of the samples tested exhibited a large amount of corrosion over the six month period which is partly due to the excess of electrolyte present as compared to the amount of zinc. Those samples which showed a small amount of corrosion after six months indicate very good inhibitive powers (small concentrations of sodium dichromate and Antaron R-155). Sodium dichromate produces a heavy film on the surface of the zinc but when this film becomes too excessive passivation of the zinc will occur as is shown in the Figure 1B. Figure 1C shows the effects of devitalized wheat gluten which is representative of all the glutens tested, while Figure 1D displays the action of special wheat protein R2E-570 which represents the proteins tested. Antarox A-403 was chosen to represent the various wetting agents and detergents used and is shown in Figure 1E.

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Of the various organic compounds analyzed as inhibitors, Quinaldine appears to give the best inhibitive action and is reported in Figure 1F.

It can be noticed in all of the polarization samples that after storage for extended periods of time, the zinc tends to show signs of passivity. In the case of sodium dichromate the passive tendency is not overcome, whereas in the case of special wheat protein R2E-570 the effect is not so strong as to render the zinc passive. These experiments do not give a clear indication of the barrier which any inhibitor will set up to prevent corrosion. They do indicate quite clearly whether any inhibitor causes passivity. If a material causes passivity it will give poor battery performance since it prevents the discharge of zinc ions. Anodic polarization data were obtained on a given sample initially and after one month storage at 113°F. A second sample stored for one month at 113°F was also tested in the same manner. This was done in order to determine if initial polarization readings affected the delayed readings. In all cases, both samples read after one month storage at 113°F gave values which closely approximate each other.

In all these samples, a slight amount of potato starch was added to the electrolyte (1 gram/40 mls) to partially immobilize it and prevent creepage of the solution up the electrodes, especially samples where wetting agents were used as inhibitors.

It is interesting to note that the samples which were tested using both unamalgamated and amalgamated zinc shows that the latter maintained a higher voltage throughout the polarization period. This should be expected because the voltage of the amalgamated zinc is normally higher than that of unamalgamated zinc. Yet anodic-cathodic polarization results of amalgamated and unamalgamated zinc show the slight corrosion barrier exhibited by amalgamated zinc (Figure #2). On this basis it would be expected that amalgamated zinc corrode badly during storage.

This was found to be especially true of amalgamated zinc when stored in electrolyte for three months at 113°F. Amalgamated zinc undergoes a weight loss five times greater than the chrome inhibited zinc and ten times greater than the zinc inhibited with Protein R2E-570, Antaron R155 or like materials.

This is not to say that amalgamation of zinc does not in some respect inhibit corrosion. The mercury does tend to level the potential of anodic and cathodic areas in the zinc. It also raises the hydrogen overvoltage making it more resistant in acid solutions. However, there is no barrier set up to prevent corrosion and if there is a tendency for any area to become either cathodic or anodic, corrosion will proceed with very little resistance in terms of polarization barriers. Results obtained from the experiments indicate that with amalgamated zinc in particular, discharge other than hydrogen ion discharge takes place without difficulty. It is quite possible therefore that hydrogen evolution is of secondary nature in the corrosion of amalgamated zinc. The first step would be the direct discharge of zinc which would in turn react with the electrolyte to liberate hydrogen.

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The second part of the experiments to evaluate inhibitors involves the measurement of both anodic and cathodic polarization at low current densities. The result of this work determines the ability of inhibitors to prevent corrosion and the amount of corrosion barrier exhibited. The experimental procedure is similar to anodic polarization and the various alterations are explained in Part I (Equipment-Procedure).

With this arrangement it is possible to measure the cathodic and anodic voltage of the zinc in the same corrosion solution under any desired polarization current. In these first experiments the polarization current was varied from a low value (0.08 ma) to a value approximating the BA-30 drain (3.5 ma). Very low polarization currents were used since the corrosion current of a battery while on shelf is very low. The higher this current becomes the faster will be the rate of corrosion. The results of nine materials tested in this manner at temperatures of 70°F, 113°F and 160°F are tabulated and shown graphically in Figure #3. These data show that some inhibitors cause very little change in either cathodic or anodic voltage as the current density is increased. Others show very rapid change in the anodic or cathodic voltage or both with a small increase in polarization current during the initial portion of the test.

For corrosion of batteries on shelf the initial parts of the curves are all that will be discussed as the polarization current is increased beyond one milliamperere, conditions approximate those of battery discharge and the curves indicate to what extent an inhibitor passivates the zinc.

An ideal inhibitor would give a sharp and rapid rise in the cathodic voltage and a rapid but moderate decrease in the anodic voltage. The inhibitor most closely approximating this in the series is Antaron R-155 (Figure 3C). This inhibitor gives a sharp increase in the cathodic voltage and a sharp decrease in anodic voltage with only a slight increase in the polarization current. Yet the overall decrease in the anodic voltage is not sufficient to indicate serious passivity.

The rapid divergence of the anodic and cathodic voltage curves is desired since it is the difference between the values of the anode and cathode at polarization current drains which give rise to a corrosion barrier.

The sample containing sodium dichromate (Figure 3a) inhibitor exhibit a higher cathodic voltage than does Antaron R-155 but this high voltage is not reached so rapidly. Also the anode polarization is small at low current drains. A second undesirable feature is the fact that the anode voltage of chrome inhibited samples continues to decrease as the current is increased instead of leveling out and this indicates that it will passivate zinc to some degree.

When Antaron and chrome (Figure 3h) were used jointly, the cathodic curve is improved over that of pure chrome but there is little effect on the anode voltage.

The use of Quinaldine (Figure 3i) as a corrosion inhibitor proved somewhat satisfactory. In the initial part of the curve, a rapid rise in the cathodic voltage occurs with only a small amount of anodic polarization. As the current increases the tendency toward passivation is not too pronounced indicating good inhibitor qualities.

Antarox A-403, Protein R2E-570, and denatured gluten give curves similar to those obtained with Antaron R-155 and Antaron with mercury but the anodic and cathodic polarization values are not as great.

On the basis of the polarization studies the following working hypothesis was evolved for samples undergoing simultaneous cathodic and anodic polarization and was used in evaluating inhibitors.

(1) An ideal inhibitor will have (a) a maximum difference between the initial open circuit voltage and cathodically polarized voltage at very low current densities, (b) a moderate anodic polarization and no evidence of gas evolution on shelf.

On the basis of anodic polarization (voltage vs. time) the following working hypothesis were developed:

(1) Four types of anodic polarization curves have been evidenced: (a) a curve showing high initial polarization with poor anodic recuperation throughout discharge, (b) a curve showing high initial polarization with rapid anodic recuperation during the discharge, (c) a curve showing very low initial polarization with little or no increase in anodic voltage during discharge, (d) a curve showing very high polarization with no recuperation (passivation).

(2) Type 1(a) indicates either very thick films or very tenacious films. They may show low corrosion but will give poor battery performance.

(3) Type 1(b) indicates a thin film which is easily removed by an anodic current. If initial anodic polarization is not too high it should give good battery performance.

(4) Type 1(c) will give excellent battery performance but corrosion will be bad unless the cathode polarization value is high.

(5) Type 1(d) indicates little corrosion will occur but destroys battery performance. If corrosion does occur it will be confined to small pits.

Figure #4 is presented to illustrate some of the various divergent curves encountered in this polarization study.

Figure #5 is a condensed graph showing the effect of chrome concentration on the corrosion barrier over various temperatures. One percent

sodium dichromate appears to be the most optimum percentage. In polarization studies, sodium dichromate was used as the source of chromate ions but it was desired to eliminate the sodium ion since it was not known what effect it had in the battery. A polarization series was run to compare the effect of sodium and ammonium dichromate and very little difference was observed in the anodic and cathodic values of the two inhibitors at any given percentage. Therefore, it was concluded that the polarization results obtained in the past using sodium dichromate would also apply for ammonium dichromate.

As a result a comprehensive comparison between ammonium chromate and ammonium dichromate was made to find which supplies the best inhibiting qualities. Polarization results of a range from 0.1% to 3.0% were obtained. Figure #6 present several of the tables and graphs for various percentages over this range. In the figures anodic polarization (in which voltage is plotted against time) is shown in the figures with the suffix A and simultaneous cathodic and anodic polarization in which voltage is plotted against polarization current is shown in the figures with the suffix B. It should also be pointed out that the cathodic and anodic polarization studies were run at a much lower current density than was the rule in previous experiments. It is felt that the range covered in these studies (0.01 ma to 0.3 ma) is of more interest in defining the inhibiting properties of any material because it more closely approximates the average corrosion current which is present in a battery when the battery is on shelf. The corrosion current will vary from cell to cell but under normal conditions (excluding internal shorts, elevated temperatures or excessive paste line or bottom washer corrosion) will fall within the current range used for these experiments.

These polarization studies were conducted at both 70°F and 160°F. In both cases the samples were allowed to stand for twenty-four hours so that equilibrium might be reached. The following general conclusions were reached based on the studies at the two temperatures.

- (1) The O.C.V. of the sample is depressed by an increase in temperature.
- (2) The tendency toward passivity is increased by increasing the temperature as shown by the anodic polarization curves where voltage is recorded with time.
- (3) The amount of cathodic polarization is decreased by an increase in temperature.
- (4) The corrosion barrier (difference between anodic and cathodic voltage at any given current density) is decreased by an increase in temperature.

Specific conclusions which were reached regarding the relative merits of ammonium dichromate and ammonium chromate as inhibitors are as follows:

- (1) Little difference was observed in the cathodic-anodic curves of

these two below 1.0%.

(2) Above 1.0% the following was true of the anodic-cathodic polarizations: (a) cathodic polarization at 70°F due to the chromate is approximately twice that due to the dichromate, (b) anodic polarization (at various currents) at both 70°F and 160°F due to the chromate is approximately half that of the dichromate, which indicates that the chromate has less of a tendency for passivity, (c) curves of anodic polarization versus time also indicate that the chromate cause less polarization at concentrations above 1.0%. Below 1.0% the curves are very similar.

(3) On the basis of the initial data shown in this report, 2.0 and 3.0%  $(\text{NH}_4)_2\text{CrO}_4$  appear to be the most promising concentrations for inhibitors in this series, exhibiting the desired characteristics of low anode polarization and high cathode polarization. This is especially true at room temperature (70°F).

The system of running polarization studies at a much lower current density (0.01 ma to 0.3 ma) was continued in further experimentation of inhibitors. Tests were made using various combinations of inhibitors, including mercury and chrome, chrome and Antarox Al<sub>4</sub>O<sub>3</sub>, mercury and Antrox Al<sub>4</sub>O<sub>3</sub>, chrome and Antaron R155, mercury and Antaron R155, chrome and Neutronyx, and mercury and Neutronyx. The individual components of these combinations were tested as a basis of comparison. The results of these studies are shown in Figure 7. It should be pointed out that Antaron R155, Antarox Al<sub>4</sub>O<sub>3</sub> and Neutronyx fall in the category of wetting agents and detergents. Antaron R155 and Antarox Al<sub>4</sub>O<sub>3</sub> are obtained from Antara Products while Neutronyx is supplied by the Onyx Oil and Chemical Company.

On the basis of anodic polarization only, where voltage is plotted versus time at a constant current density of 4.33 ma/cm<sup>2</sup>, the following conclusions were drawn.

(1) Mercury by itself (amalgamation process) gives very little anodic polarization. When a current is imposed on the zinc electrode a slight drop in voltage is evidenced immediately and the voltage then levels out and remains relatively constant. This is true of samples tested at both 70°F and 130°F.

(2) A combination of mercury and ammonium chromate gives a curve similar to that obtained from ammonium chromate alone. However, the initial voltage drop is not as severe as would be expected were the chromate the only inhibitor. At 130°F a tendency toward passivity is exhibited by this combination (See Figure 7).

(3) Antaron R155 and Antarox Al<sub>4</sub>O<sub>3</sub> show satisfactory anode polarization curves at 70°F. That is, the initial drop is not too severe and voltage recuperation takes place at a relatively rapid rate. At 130°F both materials show only a slight voltage drop and little recuperation. However, satisfactory

results should be obtained during discharge even at elevated temperatures (See Figure 7a).

(4) Combinations of mercury and Antaron and of ammonium chromate and Antaron show good anode polarization curves at 70°F. At 130°F the combination of mercury and Antaron exhibits satisfactory anode polarization while the initial voltage decrease when using ammonium chromate and Antaron is excessive and low amperage will result (See Figure 7b).

(5) Combinations of ammonium chromate and Antarox Al<sub>4</sub>O<sub>3</sub> and ammonium chromate and Neutronyx show nearly the same anodic polarization curves as the combination with Antaron RL55 with the exception that the curves obtained are better after high temperature storage.

(6) Combinations of mercury and Antarox Al<sub>4</sub>O<sub>3</sub> or mercury and Neutronyx exhibit curves similar to that obtained from mercury alone indicating that the Antarox Al<sub>4</sub>O<sub>3</sub> and Neutronyx take little part in the polarization process.

On the basis of simultaneous anodic and cathodic polarization where voltage is plotted against current densities, the following conclusions were drawn.

(1) The use of mercury as the only inhibitor gives a very slight corrosion barrier (difference between anodic and cathodic voltage at any given current density). However, in the case of mercury this does not mean that corrosion will take place rapidly since polarization is based mainly on film formation and the amalgamation process is unique in itself as previously explained (See Figure 7).

(2) Combinations of mercury and Antarox Al<sub>4</sub>O<sub>3</sub> and mercury and Neutronyx also show a very small corrosion barrier indicating as stated previously that these wetting agents take little part in the polarization process.

(3) A combination of mercury and ammonium chromate yields a curve falling approximately half way between the curves of these materials when used alone. These curves appear to have properties due to both the mercury and the chromate.

(4) Combinations of ammonium chromate and Antarox Al<sub>4</sub>O<sub>3</sub>, Antaron RL55 or Neutronyx give very good polarization curves and a relatively high corrosion barrier. This is especially true at 70°F and also holds for 130°F. The same conclusion is also reached as the result of a study of the curves exhibited by Antarox Al<sub>4</sub>O<sub>3</sub> and Antaron RL55 when used separately with the exception that Antarox Al<sub>4</sub>O<sub>3</sub> exhibits only fair curves at 130°F.

(5) The best polarization results exhibited in this series is obtained from a combination of mercury and Antaron RL55. The curves for this combination are shown in Figure 7b. The polarization for this combination at 70°F is ideal, based on the hypothesis given early in this section. Excellent polarization

is also exhibited by this combination when tested at 130°F.

In the above series the samples were allowed to stand for twenty-four hours, at the required temperature in order for equilibrium to be attained.

In all cases, with the exception of mercury, the percentage given was by weight of the electrolyte used. Where mercury was used the percentage of mercury involved was calculated from the area of the zinc electrodes.

#### B. Inhibitors and Corrosion Studies

Visual corrosion studies have been conducted to substantiate data already obtained on various inhibitors from polarization studies. In these experiments, strips of zinc were stored in electrolytes containing various inhibitors in different percentages. Two strips of zinc were included in each sample, one of which was completely immersed in the electrolyte solution while the other was only partially immersed. The latter strip was included to study the corrosion which occurred at the air line. These samples were stored at 113°F and inspected and weighed periodically. Data obtained from these studies are shown in Figures 8 (zinc partially immersed) and 9 (zinc totally immersed). These data include the weight of the zinc strip initially and after twelve months storage at 113°F and also the percentage of weight loss during this period. In cases where complete corrosion occurred at the air line, the data have not been included because of the inaccuracy involved.

The results obtained from these studies coincide very well with those obtained from polarization studies. The dichromate film gives by far the best inhibition of the materials tested. As shown in the polarization studies 1.0% sodium dichromate appears to be the most optimum percentage (see Figure 5). However, the polarization studies indicated a very substantial degree of passivity with this percentage and hence it is felt that best results on the basis of good inhibition and capacity can be obtained using 0.3 to 0.5% sodium dichromate by weight of electrolyte in the separator.

Good results were also obtained from Antaron R-155 and some of the proteins especially Special Wheat Protein R2E-570 and R2E-1301 which were obtained from General Mills, Inc.

With the exception of those samples containing mercury, corrosion over the zinc surface was quite even. Some pitting was noted in the samples having Sequestrene NA2 and NA4 as the inhibitor and a heavy pitting type attack was observed in the amalgamated sample.

As stated previously the chromate process for inhibiting in cells stored at high temperatures appear to be quite satisfactory whereas the amalgamation process does not.

Conclusions

1. An ideal inhibitor for battery application should cause zinc to exhibit high cathodic polarization and moderate anodic polarization.
2. The amalgamation of zinc tends to equalize the voltage of the anodic and cathodic areas on the zinc surface. However, no appreciable corrosion barrier is exhibited by amalgamated zinc and any variation in potential on the surface will cause corrosion. This corrosion process will proceed with little impedance.
3. Corrosion of amalgamated zinc does not appear to involve a direct liberation of hydrogen. The corrosion process probably involves a discharge of free zinc, which because it is a finely divided and active form, reacts directly with the electrolyte to liberate hydrogen. This hypothesis is based on the fact that the low cathode polarization does not seem to be compatible with the high hydrogen overvoltage of amalgamated zinc as recognized in literature.
4. Weight loss measurements show dichromate, Antaron R-155 and protein materials to be the best inhibitor materials tested to date.
5. It is not possible to obtain as good inhibition at elevated temperatures as can be obtained with the same material at room temperature.
6. Polarization studies of ammonium chromate and ammonium dichromate show the former to be superior as an inhibitor especially at the higher percentages. Percentages of 2.0% and 3.0% ammonium chromate by weight of electrolyte gave excellent initial results.
7. A combination of mercury and Antaron R-155 as an inhibitor gave an ideal anodic-cathodic polarization curve. This combination should give very good inhibitor properties especially at room temperature.

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TABLES AND GRAPHS

PART V

POLARIZATION STUDIES - CORROSION INHIBITORS

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FIGURE 1

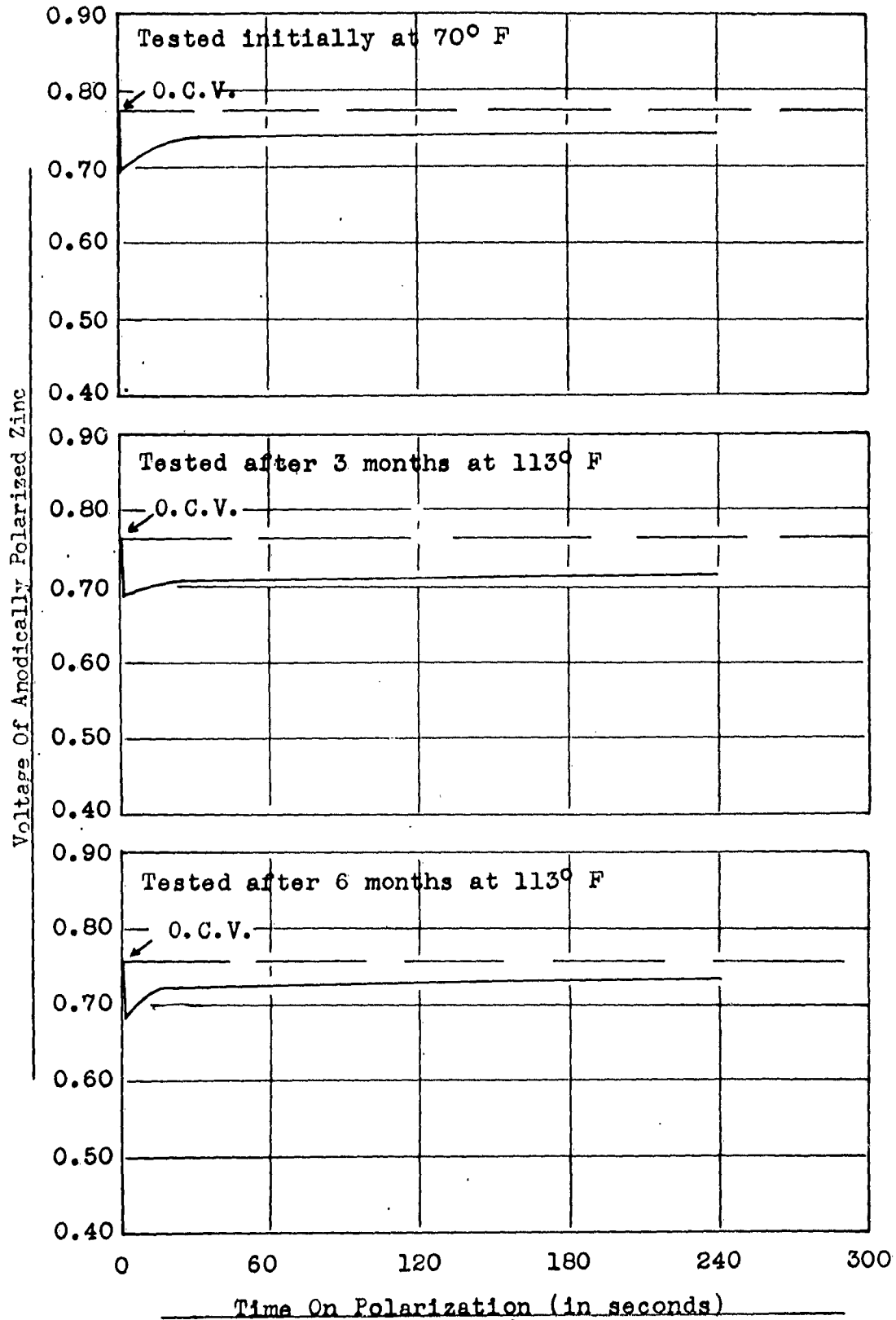
Anodic Polarization of Zinc

Series No.	1		
Type of sample	Electrolyte - Potato Starch (40 mls/1 gr) Inhibitor - None, Unamalgamated zinc only		
Anodic Polarization Current Density		4.33 ma/sq.cm.	
	Reading taken initially at 70° F.	Reading taken after 3 months at 113° F.	Reading taken after 6 months at 113° F.
O.C.V. before polarization	0.775 v.	0.761 v.	0.755 v.
Time on polarization	Anodic Voltage		
1 second	0.698 v.	0.688 v.	0.683 v.
15 seconds	0.728 v.	0.702 v.	0.721 v.
30 seconds	0.738 v.	0.706 v.	0.724 v.
45 seconds	0.739 v.	0.707 v.	0.726 v.
60 seconds	0.740 v.	0.708 v.	0.726 v.
75 seconds	0.740 v.	0.710 v.	0.728 v.
90 seconds	0.740 v.	0.710 v.	0.728 v.
105 seconds	0.740 v.	0.711 v.	0.730 v.
120 seconds	0.740 v.	0.711 v.	0.730 v.
180 seconds	0.740 v.	0.712 v.	0.730 v.
240 seconds	0.739 v.	0.713 v.	0.730 v.

FIGURE 1 (Cont.)

ANODIC POLARIZATION OF ZINC

No Inhibitor - Control



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FIGURE 1a

Anodic Polarization of Zinc

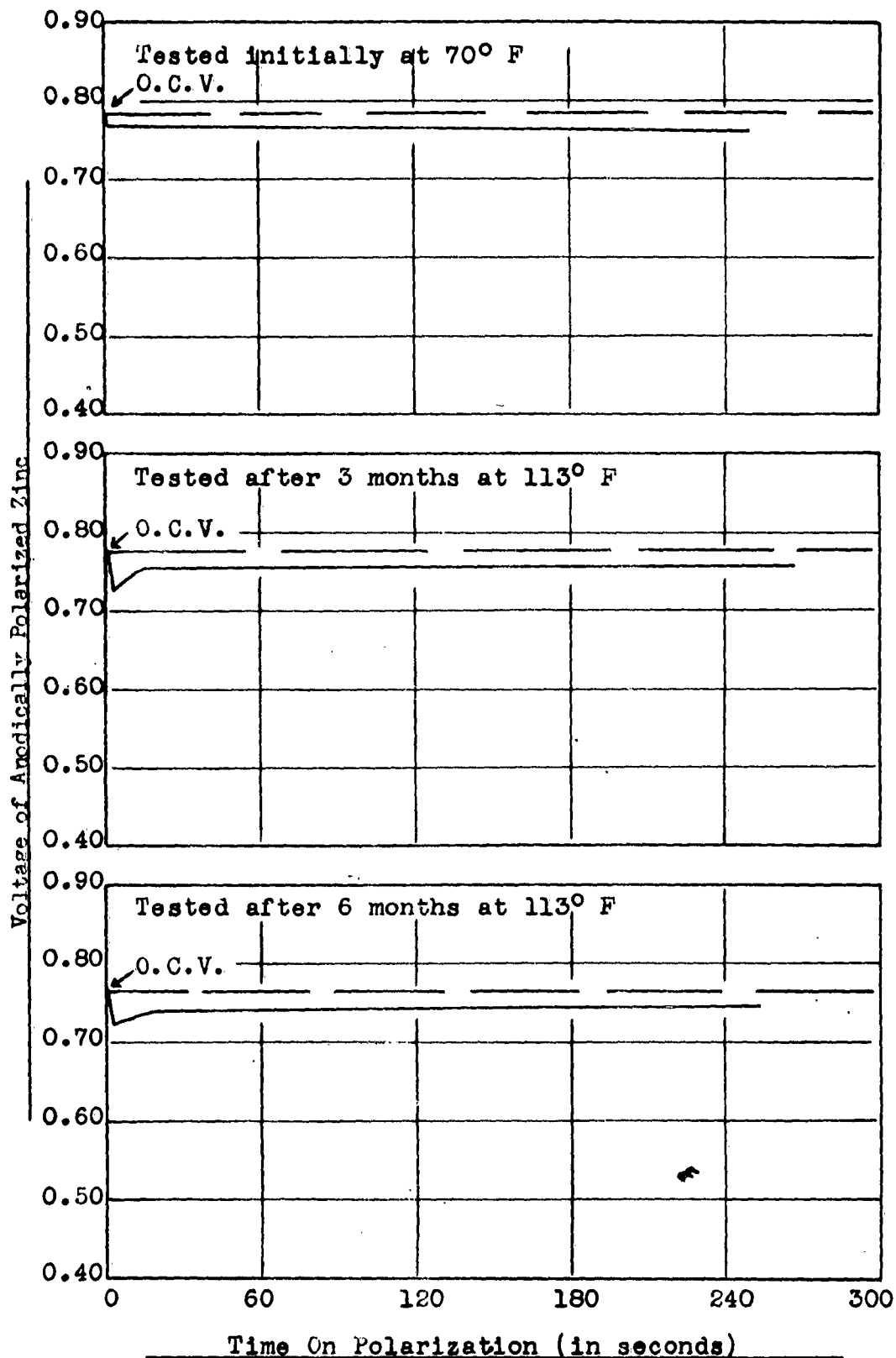
Series No.	8		
Type of sample	Electrolyte - Potato Starch (40 mls/1 gr) Inhibitor - 0.20% Hg in Zn		
Anodic Polarization Current Density		4.33 ma/sq.cm.	
	Reading taken initially at 70°F	Reading taken after 3 months at 113° F	Reading taken after 6 months at 113° F
O.C.V. before polarization	0.785 v.	0.777 v.	0.762 v.
Time on polarization	Anodic Voltage		
1 second	0.768 v.	0.728 v.	0.723 v.
15 seconds	0.769 v.	0.754 v.	0.738 v.
30 seconds	0.769 v.	0.755 v.	0.740 v.
45 seconds	0.769 v.	0.756 v.	0.741 v.
60 seconds	0.768 v.	0.756 v.	0.741 v.
75 seconds	0.767 v.	0.756 v.	0.742 v.
90 seconds	0.767 v.	0.757 v.	0.743 v.
105 seconds	0.766 v.	0.757 v.	0.743 v.
120 seconds	0.766 v.	0.757 v.	0.743 v.
180 seconds	0.764 v.	0.757 v.	0.745 v.
240 seconds	0.763 v.	0.758 v.	0.745 v.

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FIGURE 1(a) Cont.

ANODIC POLARIZATION OF ZINC

Inhibitor - 0.20% Hg in Zn



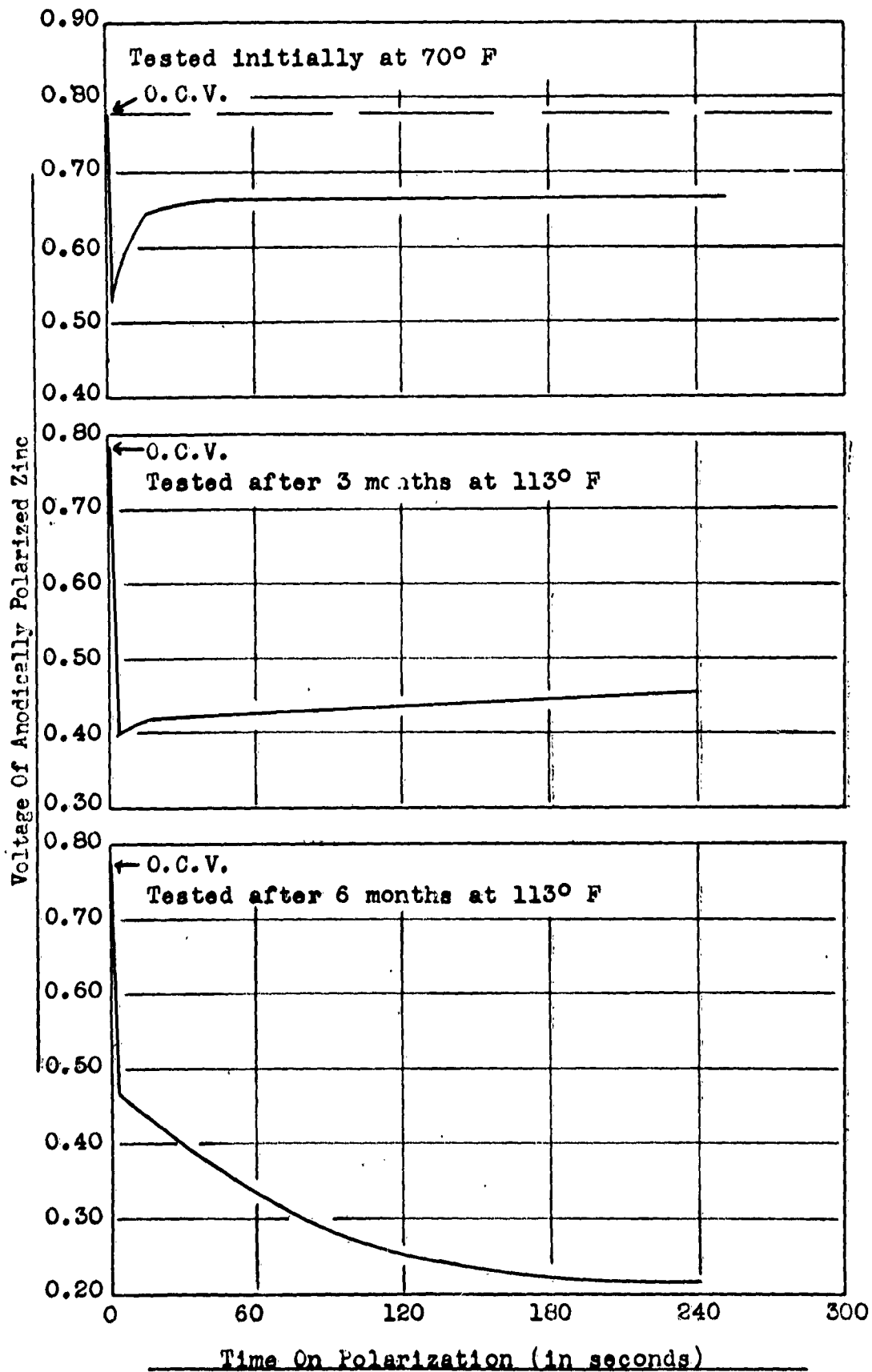
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FIGURE 1(b)

Anodic Polarization of Zinc

Series No.	15		
Type of sample	Electrolyte - Potato Starch (40 mls/l gr) Inhibitor - 0.50% Sodium Dichromate		
Anodic Polarization Current Density		4.33 ma/sq.cm.	
	Reading taken initially at 70°F	Reading taken after 3 months at 113°F	Reading taken after 6 months at 113°F
O.C.V. before polarization	0.718 v.	0.781 v.	0.774 v.
Time on polarization	Anodic Voltage		
1 second	0.528 v.	0.398 v.	0.468 v.
15 seconds	0.648 v.	0.423 v.	0.428 v.
30 seconds	0.659 v.	0.416 v.	0.397 v.
45 seconds	0.663 v.	0.424 v.	0.368 v.
60 seconds	0.664 v.	0.426 v.	0.348 v.
75 seconds	0.664 v.	0.422 v.	0.298 v.
90 seconds	0.664 v.	0.428 v.	0.284 v.
105 seconds	0.665 v.	0.433 v.	0.270 v.
120 seconds	0.665 v.	0.436 v.	0.253 v.
180 seconds	0.664 v.	0.448 v.	0.227 v.
240 seconds	0.664 v.	0.452 v.	0.217 v.

FIGURE 1(b)Cont.  
ANODIC POLARIZATION OF ZINC  
Inhibitor - 0.50%  $\text{Na}_2\text{Cr}_2\text{O}_7$



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FIGURE 1(c)

Anodic Polarization of Zinc

Series No.	3		
Type of sample	Electrolyte - Potato Starch (40 mls/1 gr) Inhibitor - 1.0% Wheat Gluten (unamal. zinc)		
Anodic Polarization Current Density		4.33 ma/sq.cm.	
	Reading taken initially at 70° F	Reading taken after 3 months at 113° F	Reading taken after 6 months at 113° F
O.C.V. before polarization	0.783 v.	0.775 v.	0.770 v.
Time on polarization	Anodic Polarization		
1 second	0.708 v.	0.698 v.	0.678 v.
15 seconds	0.738 v.	0.726 v.	0.709 v.
30 seconds	0.741 v.	0.730 v.	0.715 v.
45 seconds	0.744 v.	0.733 v.	0.717 v.
60 seconds	0.746 v.	0.736 v.	0.719 v.
75 seconds	0.747 v.	0.737 v.	0.720 v.
90 seconds	0.748 v.	0.738 v.	0.721 v.
105 seconds	0.749 v.	0.739 v.	0.722 v.
120 seconds	0.749 v.	0.740 v.	0.723 v.
180 seconds	0.751 v.	0.743 v.	0.724 v.
240 seconds	0.751 v.	0.745 v.	0.726 v.

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FIGURE 1(c) Cont.

Anodic Polarization of Zinc

Series No	43		
Type of sample	Electrolyte - Potato Starch (40 mls/1 gr) Inhibitor - 1.0% Wheat Gluten and amal. zinc		
Anodic Polarization Current Density		4.33 ma/sq.cm.	
	Reading taken initially at 70° F	Reading taken after 3 months at 113° F	Reading taken after 6 months at 113° F
O.C.V. before polarization	0.801 v.	0.796 v.	0.794 v.
Time on polarization	Anodic Voltage		
1 second	0.758 v.	0.738 v.	0.643 v.
15 seconds	0.772 v.	0.750 v.	0.758 v.
30 seconds	0.776 v.	0.754 v.	0.761 v.
45 seconds	0.778 v.	0.757 v.	0.763 v.
60 seconds	0.779 v.	0.759 v.	0.764 v.
75 seconds	0.780 v.	0.760 v.	0.765 v.
90 seconds	0.780 v.	0.761 v.	0.765 v.
105 seconds	0.781 v.	0.762 v.	0.766 v.
120 seconds	0.781 v.	0.763 v.	0.767 v.
180 seconds	0.781 v.	0.765 v.	0.768 v.
240 seconds	0.781 v.	0.766 v.	0.764 v.

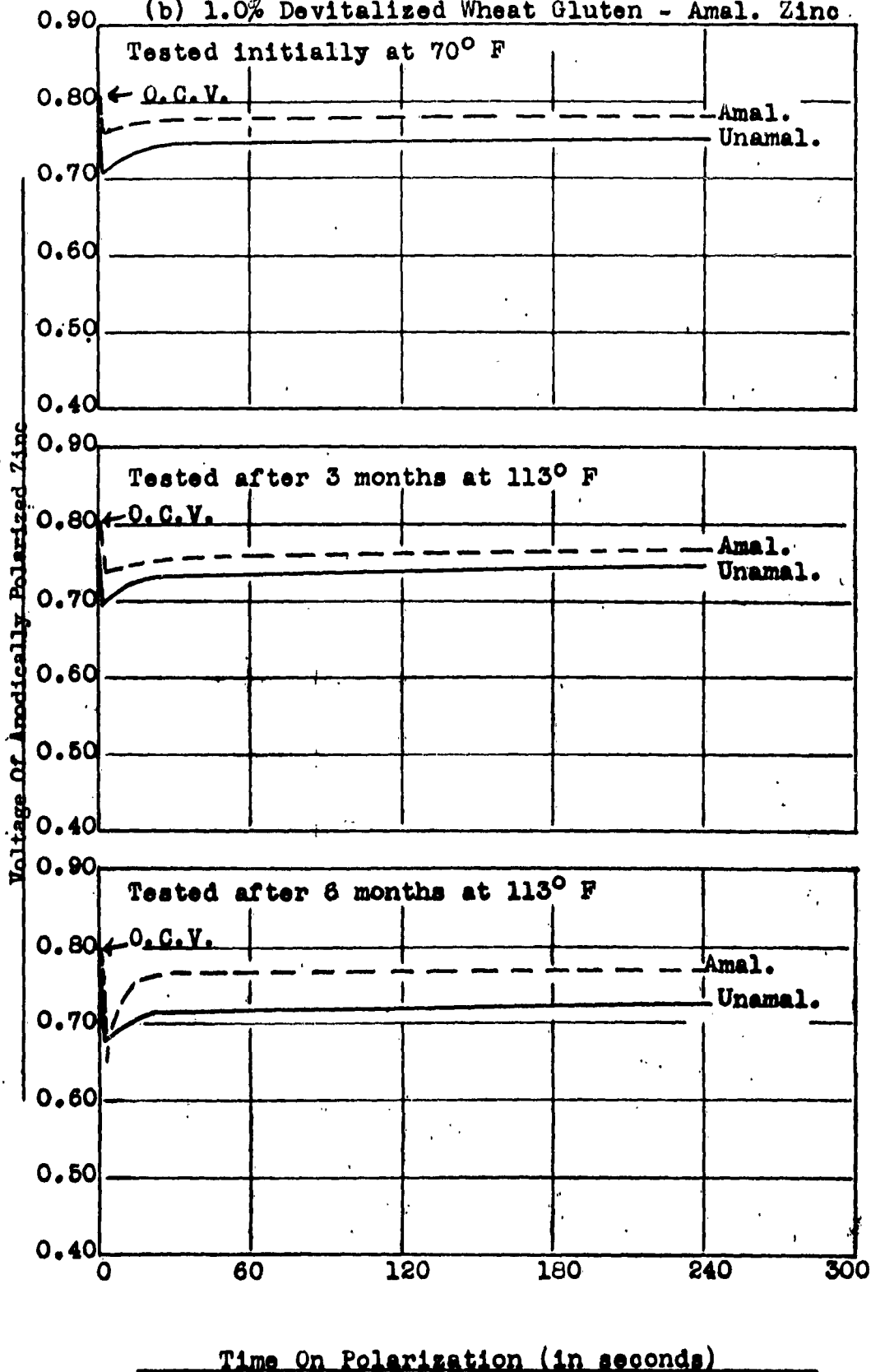
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FIGURE 1(c) Cont.

ANODIC POLARIZATION OF ZINC

(a) 1.0% Devitalized Wheat Gluten

(b) 1.0% Devitalized Wheat Gluten - Amal. Zinc



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FIGURE 1(d)

Anodic Polarization of Zinc

Series No.	4		
Type of sample	Electrolyte - Potato Starch (40 mls/1 gr) Inhibitor - 1.0% Protein R2E-570 (unamal. zinc)		
Anodic Polarization Current Density		4.33 ma/sq.cm.	
	Reading taken initially at 70° F	Reading taken after 3 months at 113° F	Reading taken after 6 months at 113° F
O.C.V. before polarization	0.781 v.	0.767 v.	0.757 v.
Time on polarization	Anodic Voltage		
1 second	0.678 v.	0.658 v.	0.681 v.
15 seconds	0.718 v.	0.701 v.	0.699 v.
30 seconds	0.736 v.	0.711 v.	0.717 v.
45 seconds	0.741 v.	0.716 v.	0.719 v.
60 seconds	0.742 v.	0.719 v.	0.720 v.
75 seconds	0.744 v.	0.722 v.	0.722 v.
90 seconds	0.744 v.	0.724 v.	0.723 v.
105 seconds	0.745 v.	0.726 v.	0.724 v.
120 seconds	0.746 v.	0.727 v.	0.725 v.
180 seconds	0.747 v.	0.731 v.	0.727 v.
240 seconds	0.748 v.	0.733 v.	0.728 v.

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FIGURE 1(d) Cont.

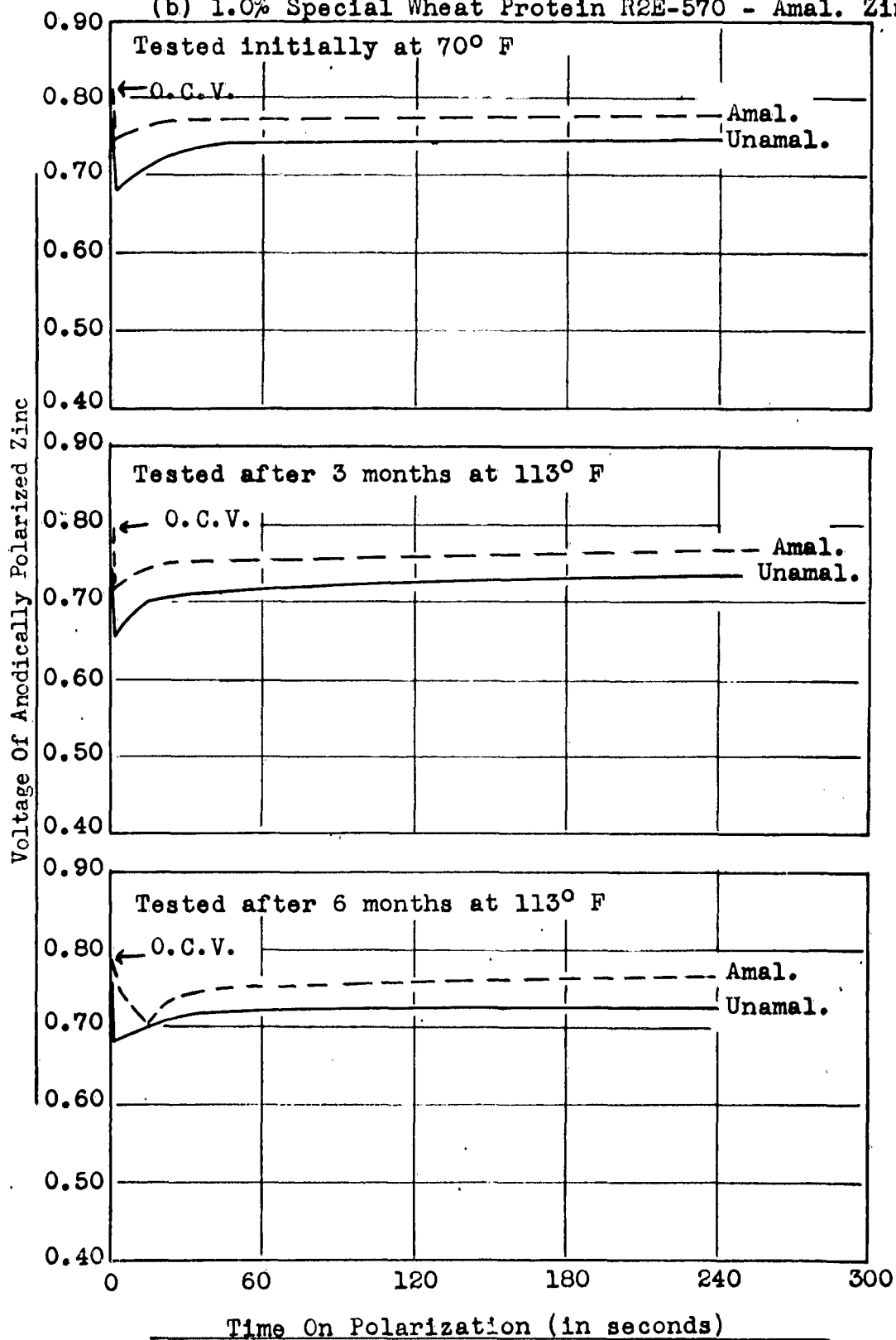
Anodic Polarization of Zinc

Series No.	44		
Type of sample	Electrolyte - Potato Starch (40 mls/1 gr) Inhibitor - 1.0% Protein R2E570 and amal. zinc		
Anode Polarization Current Density		4.33 ma/sq.cm.	
	Reading taken initially at 70° F	Reading taken after 3 months at 113° F	Reading taken after 6 months at 113° F
O.C.V. before polarization	0.801 v.	0.795 v.	0.784 v.
Time on polarization	Anodic Voltage		
1 second	0.748 v.	0.718 v.	0.754 v.
15 seconds	0.769 v.	0.748 v.	0.713 v.
30 seconds	0.771 v.	0.750 v.	0.741 v.
45 seconds	0.773 v.	0.752 v.	0.747 v.
60 seconds	0.774 v.	0.754 v.	0.749 v.
75 seconds	0.774 v.	0.756 v.	0.751 v.
90 seconds	0.775 v.	0.757 v.	0.754 v.
105 seconds	0.775 v.	0.758 v.	0.755 v.
120 seconds	0.775 v.	0.759 v.	0.756 v.
180 seconds	0.775 v.	0.762 v.	0.766 v.
240 seconds	0.775 v.	0.764 v.	0.767 v.

FIGURE 1(d) Cont.  
ANODIC POLARIZATION OF ZINC

(a) 1.0% Special Wheat Protein R2E-570

(b) 1.0% Special Wheat Protein R2E-570 - Amal. Zinc



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FIGURE 1(e)

Anodic Polarization of Zinc

Series No.	28		
Type of sample	Electrolyte - Potato Starch (40 mls/1 gr) Inhibitor - 0.20% Antarox A-403 (unamal. zinc)		
Anodic Polarization Current Density		4.33 ma/sq.cm.	
	Reading taken initially at 70° F	Reading taken after 3 months at 113° F	Reading taken after 6 months at 113° F
O.C.V. before polarization	0.789 v.	0.762 v.	0.338 v.
Time on polarization	Anodic Voltage		
1 second	0.688 v.	0.628 v.	0.168 v.
15 seconds	0.722 v.	0.675 v.	0.068 v.
30 seconds	0.728 v.	0.684 v.	0.052 v.
45 seconds	0.732 v.	0.689 v.	0.051 v.
60 seconds	0.733 v.	0.692 v.	0.052 v.
75 seconds	0.735 v.	0.693 v.	0.050 v.
90 seconds	0.736 v.	0.695 v.	0.045 v.
105 seconds	0.736 v.	0.696 v.	0.040 v.
120 seconds	0.737 v.	0.697 v.	0.036 v.
180 seconds	0.739 v.	0.700 v.	0.019 v.
240 seconds	0.739 v.	0.702 v.	0.010 v.

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FIGURE 1(e) Cont.

Anodic Polarization of Zinc

Series No.	33		
Type of sample	Electrolyte - Potato Starch (40 mls/l gr) Inhibitor - 0.20% Antarox A-403 and amal. zinc		
Anodic Polarization Current Density		4.33 ma/sq.cm.	
	Reading taken initially at 70° F.	Reading taken after 3 months at 113° F.	Reading taken after 6 months at 113° F.
O.C.V. before polarization	0.801 v.	0.795 v.	0.768 v.
Time on polarization	Anodic Voltage		
1 second	0.698 v.	0.718 v.	0.648 v.
15 seconds	0.739 v.	0.704 v.	0.669 v.
30 seconds	0.744 v.	0.699 v.	0.678 v.
45 seconds	0.746 v.	0.697 v.	0.682 v.
60 seconds	0.747 v.	0.697 v.	0.685 v.
75 seconds	0.747 v.	0.699 v.	0.687 v.
90 seconds	0.747 v.	0.701 v.	0.689 v.
105 seconds	0.747 v.	0.703 v.	0.691 v.
120 seconds	0.747 v.	0.704 v.	0.692 v.
180 seconds	0.747 v.	0.711 v.	0.698 v.
240 seconds	0.747 v.	0.715 v.	0.700 v.

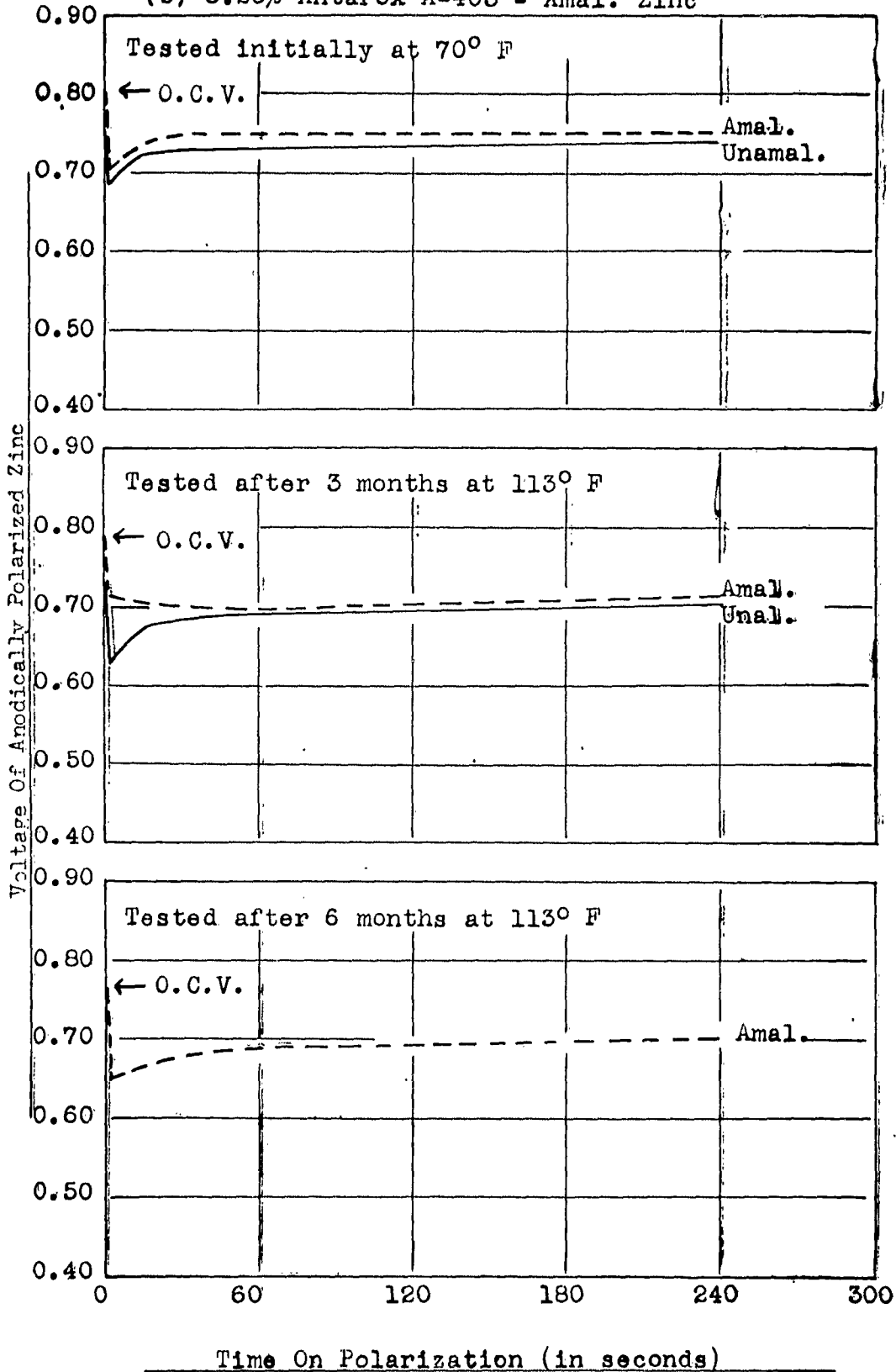
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FIGURE 1(e) Cont.

ANODIC POLARIZATION OF ZINC

(a) Inhibitor - 0.20% Antarox A-403

(b) 0.20% Antarox A-403 - Amal. Zinc



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FIGURE 1(f)

Anodic Polarization of Zinc

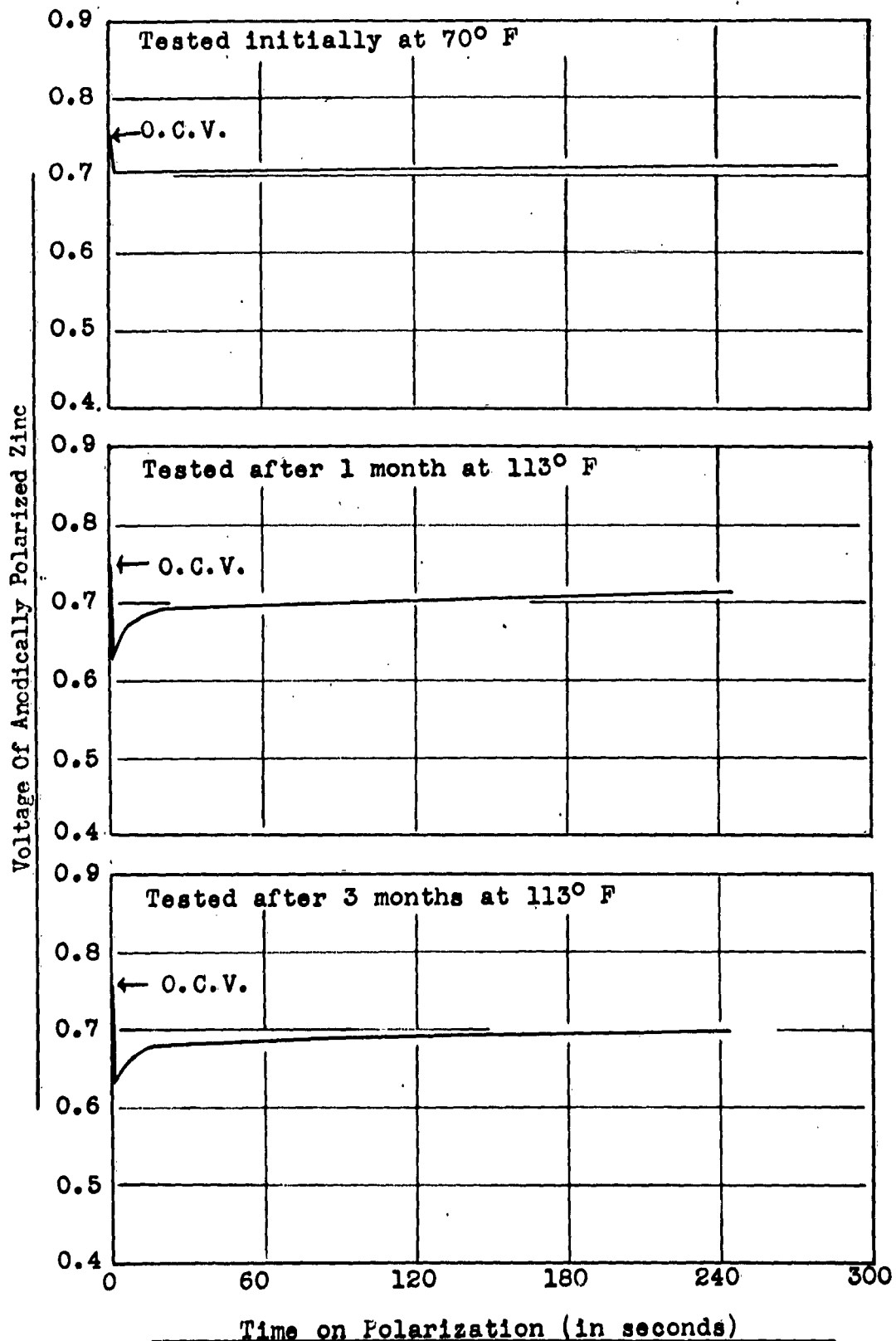
Series No.	47		
Type of sample	Electrolyte - Potato starch (40 ml/1 gr.) Inhibitor - 0.1% Quinaldine - unamal. zinc		
Anodic polarization current density		4.33 ma/sq.cm.	
	Initial reading at 70° F.	Reading after 1 month storage at 113° F.	Reading after 3 months storage at 113° F.
O.C.V. before polarization	0.748 v.	0.749 v.	0.752 v.
Time on polarization	Anode Voltage		
1 second	0.708 v.	0.638 v.	0.638v.
15 seconds	0.708 v.	0.690 v.	0.678 v.
30 seconds	0.709 v.	0.695 v.	0.683 v.
45 seconds	0.710 v.	0.698 v.	0.686 v.
60 seconds	0.710 v.	0.7 01 v.	0.688 v.
75 seconds	0.710 v.	0.703 v.	0.690 v.
90 seconds	0.711 v.	0.705 v.	0.691 v.
105 seconds	0.711 v.	0.706 v.	0.692 v.
120 seconds	0.711 v.	0.707 v.	0.694 v.
180 seconds	0.712 v.	0.711 v.	0.697 v.
240 seconds	0.713 v.	0.713 v.	0.699 v.

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FIGURE 1(f) Cont.

ANODIC POLARIZATION OF ZINC

Inhibitor - 0.1% Quinaldine - Unamal. Zinc



# ANODIC AND CATHODIC POLARIZATION

VOLTAGE OF ANODICALLY AND CATHODICALLY

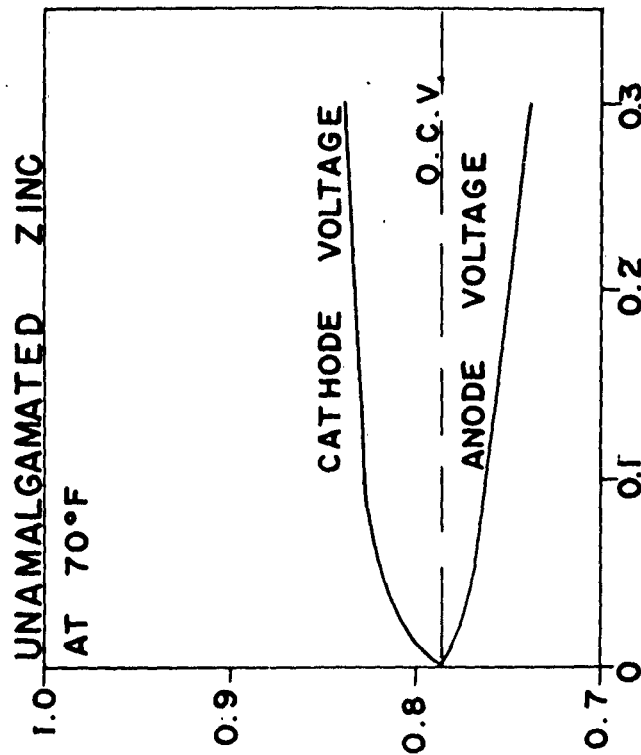
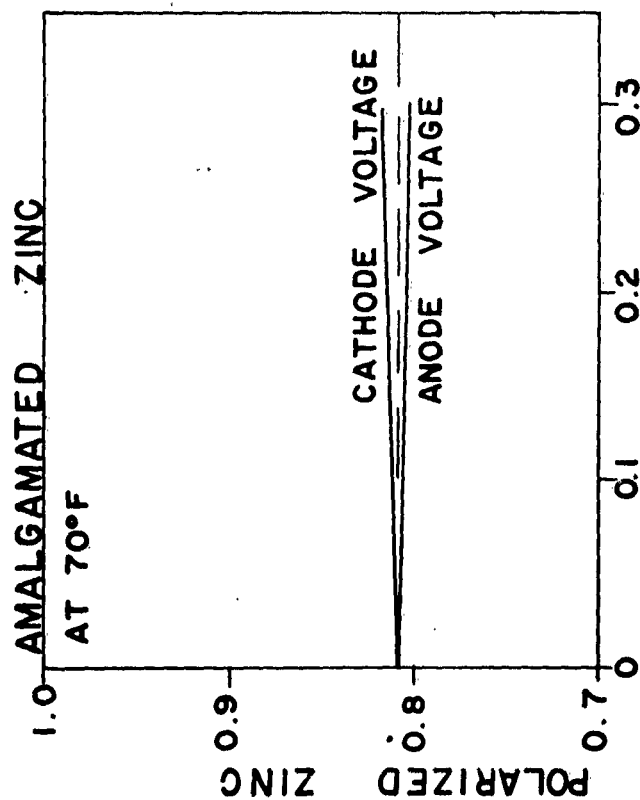


FIGURE 2

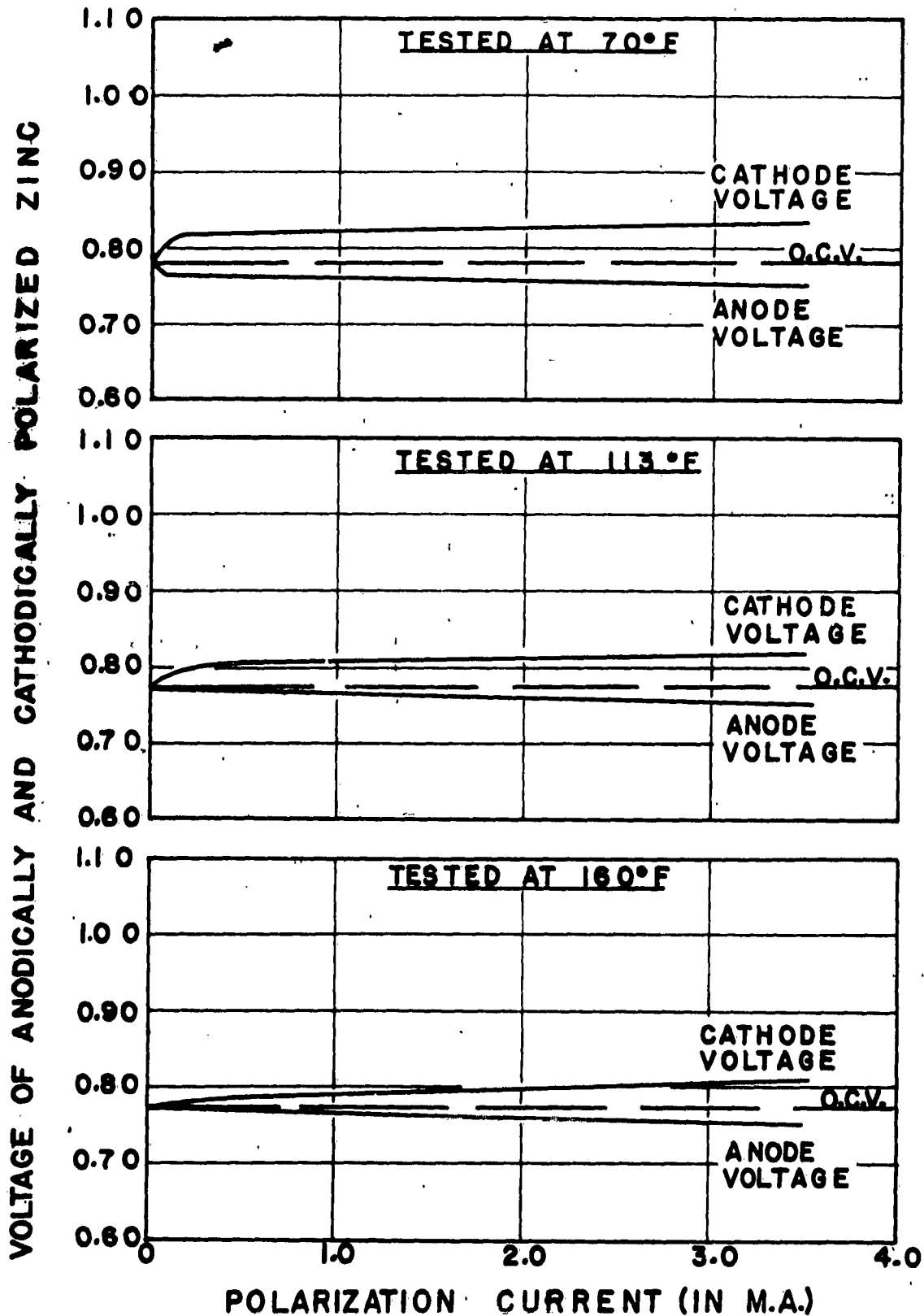
CURRENT DRAIN PER 0.785 SQ. CM. OF ZINC (IN MA.)

FIGURE 3

Anodic and Cathodic Polarization of Zinc						
Sample No.				A-0		
Type of sample	Electrolyte - Potato Starch (40 mls/1 gm.) with no inhibitor - unamalgamated zinc only.					
Electrolyte Composition			24% NH <sub>4</sub> Cl ; 22.5% ZnCl <sub>2</sub> ; 53.5% H <sub>2</sub> O (Composition by weight)			
Area of zinc anode		0.785 sq.cm.		Area of zinc cathode		0.785 sq.cm.
	Tested @ 70°F		Tested @ 113°F		Tested @ 160°F	
	O.C.V.	0.780 v.	O.C.V.	0.776 v.	O.C.V.	0.773 v.
Polarization Current	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage
0.08 ma.	0.767 v.	0.810 v.	0.772 v.	0.790 v.	0.772 v.	0.777 v.
0.16 ma.	0.766 v.	0.818 v.	0.769 v.	0.797 v.	0.771 v.	0.779 v.
0.30 ma.	0.766 v.	0.819 v.	0.767 v.	0.801 v.	0.768 v.	0.784 v.
0.50 ma.	0.765 v.	0.821 v.	0.767 v.	0.807 v.	0.767 v.	0.787 v.
1.00 ma.	0.761 v.	0.824 v.	0.764 v.	0.811 v.	0.764 v.	0.793 v.
1.50 ma.	0.759 v.	0.828 v.	0.761 v.	0.812 v.	0.762 v.	0.796 v.
2.00 ma.	0.757 v.	0.828 v.	0.758 v.	0.812 v.	0.759 v.	0.800 v.
2.50 ma.	0.756 v.	0.831 v.	0.756 v.	0.815 v.	0.758 v.	0.802 v.
3.00 ma.	0.753 v.	0.832 v.	0.755 v.	0.817 v.	0.755 v.	0.805 v.
3.50 ma.	0.752 v.	0.834 v.	0.753 v.	0.820 v.	0.753 v.	0.807 v.

### FIGURE 3

ANODIC AND CATHODIC POLARIZATION OF ZINC  
SAMPLE A-0 (NO INHIBITOR)



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FIGURE 3(a)

Anodic and Cathodic Polarization of Zinc						
Sample No.				A-1		
Type of sample	Electrolyte - Potato Starch (40 mls/1 gm.) with 0.20% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> as inhibitor					
Electrolyte Composition			24% NH <sub>4</sub> Cl ; 22.5% ZnCl <sub>2</sub> ; 53.5% H <sub>2</sub> O (Composition by weight)			
Area of zinc anode		0.785 sq.cm.		Area of zinc cathode		0.785 sq.cm.
	Tested at 70°F		Tested at 113°F		Tested at 160°F	
	O.C.V.	0.793 v.	O.C.V.	0.780 v.	O.C.V.	0.778 v.
Polarization Current	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage
0.08 ma.	0.779 v.	0.797 v.	0.768 v.	0.800 v.	0.775 v.	0.787 v.
0.16 ma.	0.772 v.	0.839 v.	0.761 v.	0.812 v.	0.764 v.	0.807 v.
0.30 ma.	0.772 v.	0.987 v.	0.750 v.	0.835 v.	0.749 v.	0.822 v.
0.50 ma.	0.768 v.	0.999 v.	0.732 v.	0.847 v.	0.739 v.	0.827 v.
1.00 ma.	0.761 v.	1.032 v.	0.709 v.	0.906 v.	0.712 v.	0.839 v.
1.50 ma.	0.744 v.	1.033 v.	0.672 v.	0.958 v.	0.697 v.	0.844 v.
2.00 ma.	0.735 v.	1.033 v.	0.651 v.	0.955 v.	0.688 v.	0.853 v.
2.50 ma.	0.725 v.	1.031 v.	0.639 v.	0.958 v.	0.676 v.	0.883 v.
3.00 ma.	0.717 v.	1.035 v.	0.633 v.	0.963 v.	0.673 v.	0.933 v.
3.50 ma.	0.709 v.	1.034 v.	0.635 v.	0.988 v.	0.663 v.	0.931 v.

**FIGURE 3A**

**ANODIC AND CATHODIC POLARIZATION OF ZINC  
SAMPLE A-1 (INHIBITOR - .20%  $\text{Na}_2\text{Cr}_2\text{O}_7$ )**

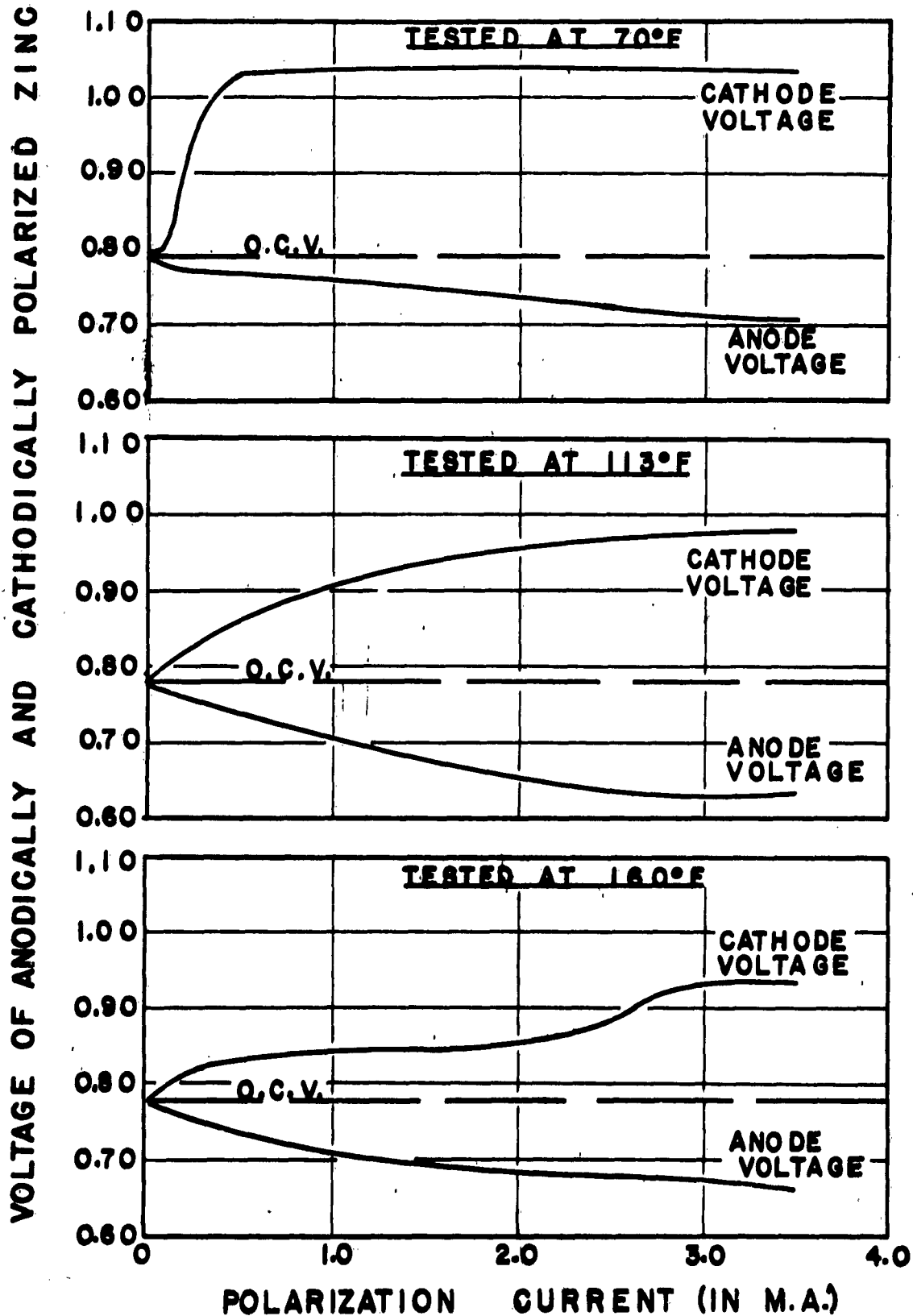


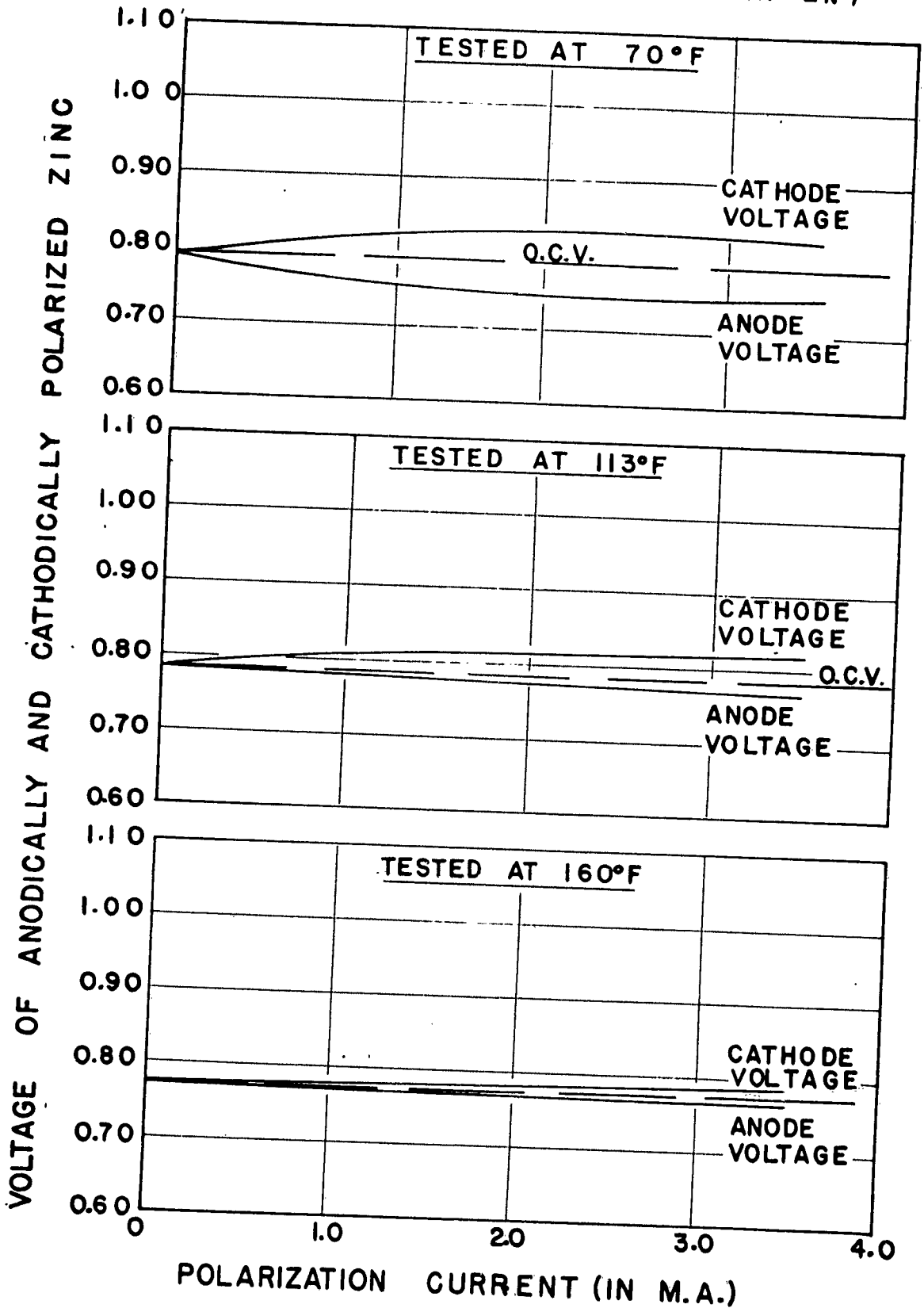
FIGURE 3(b)

Anodic and Cathodic Polarization of Zinc						
Sample No.				A-2		
Type of sample	Electrolyte - Potato Starch (40 mls/1 gm.) with 0.25% Mercury in Zinc as inhibitor.					
Electrolyte Composition		24% NH <sub>4</sub> Cl ; 22.5% ZnCl <sub>2</sub> ; 53.5% H <sub>2</sub> O (Composition by weight)				
Area of zinc anode		0.785 sq.cm.		Area of zinc cathode		0.785 sq.cm.
	Tested at 70°F		Tested at 113°F		Tested at 160°F	
	O.C.V.	0.790 v.	O.C.V.	0.785 v.	O.C.V.	0.776 v.
Polarization Current	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage
0.08 ma.	0.785 v.	0.791 v.	0.785 v.	0.786 v.	0.776 v.	0.776 v.
0.16 ma.	0.781 v.	0.794 v.	0.784 v.	0.788 v.	0.776 v.	0.776 v.
0.30 ma.	0.775 v.	0.798 v.	0.783 v.	0.791 v.	0.775 v.	0.777 v.
0.50 ma.	0.767 v.	0.804 v.	0.782 v.	0.797 v.	0.775 v.	0.778 v.
1.00 ma.	0.756 v.	0.818 v.	0.780 v.	0.808 v.	0.773 v.	0.779 v.
1.50 ma.	0.750 v.	0.831 v.	0.778 v.	0.816 v.	0.772 v.	0.781 v.
2.00 ma.	0.746 v.	0.828 v.	0.776 v.	0.818 v.	0.771 v.	0.782 v.
2.50 ma.	0.752 v.	0.829 v.	0.775 v.	0.818 v.	0.770 v.	0.784 v.
3.00 ma.	0.750 v.	0.827 v.	0.772 v.	0.819 v.	0.770 v.	0.786 v.
3.50 ma.	0.752 v.	0.829 v.	0.770 v.	0.821 v.	0.769 v.	0.788 v.

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FIGURE 3a

ANODIC AND CATHODIC POLARIZATION OF ZINC  
SAMPLE A-2 (INHIBITOR - .25% Hg IN ZN)



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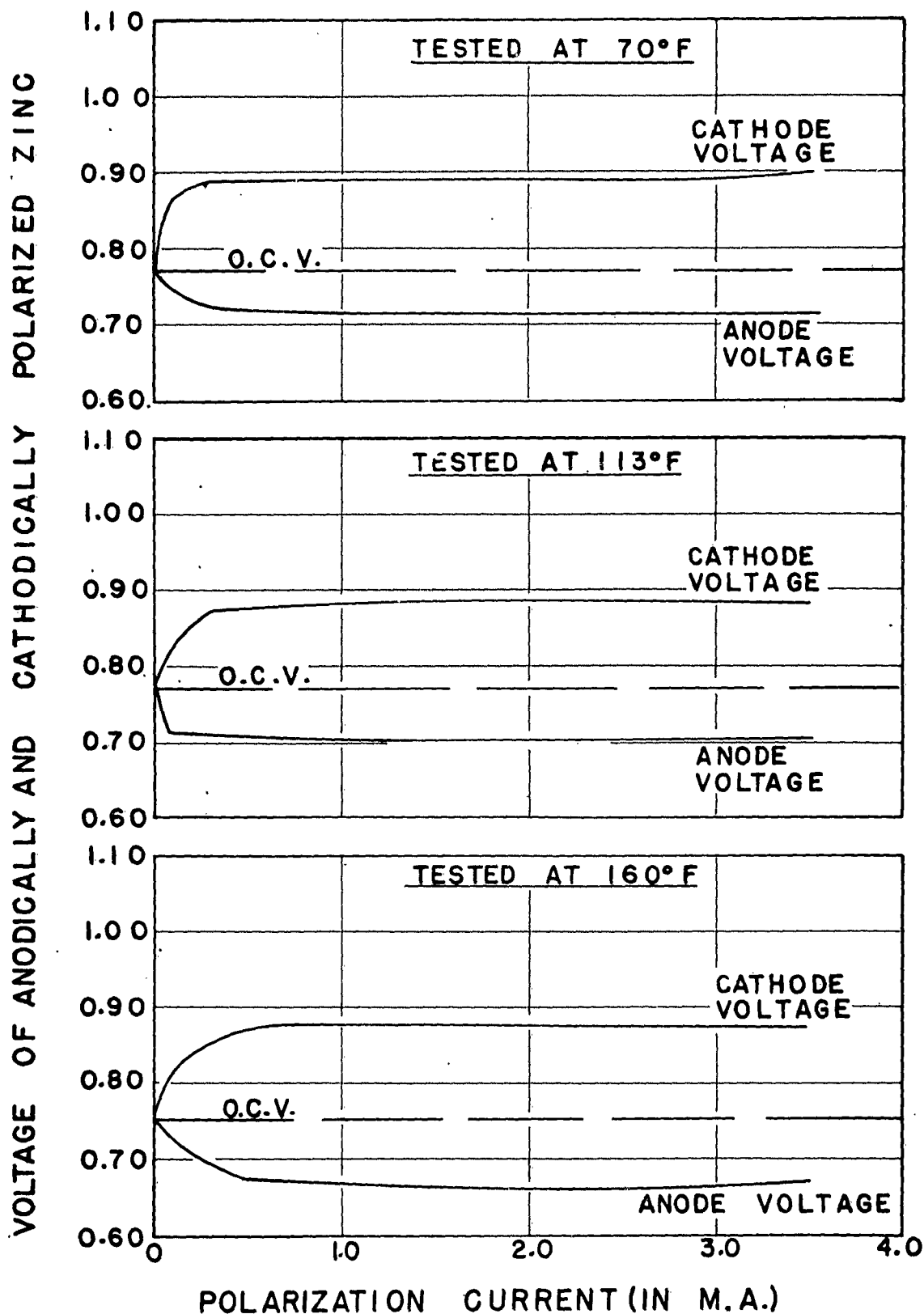
FIGURE 3(c)

Anodic and Cathodic Polarization of Zinc						
Sample No.				A-3		
Type of sample	Electrolyte - Potato Starch (40 mls/1 gm.) with 0.20% Antaron R-155 as inhibitor					
Electrolyte Composition			24% NH <sub>4</sub> CL ; 22.5% ZnCl <sub>2</sub> ; 53.5% H <sub>2</sub> O (Composition by weight)			
Area of zinc anode		0.785 sq.cm.		Area of zinc cathode		0.785 sq.cm.
	Tested at 70°F		Tested at 113°F		Tested at 160°F	
	O.C.V.	0.771 v.	O.C.V.	0.773 v.	O.C.V.	0.753 v.
Polarization Current	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage
0.08 ma.	0.749 v.	0.867 v.	0.715 v.	0.825 v.	0.730 v.	0.808 v.
0.16 ma.	0.731 v.	0.874 v.	0.712 v.	0.848 v.	0.715 v.	0.829 v.
0.30 ma.	0.730 v.	0.890 v.	0.709 v.	0.877 v.	0.693 v.	0.850 v.
0.50 ma.	0.720 v.	0.887 v.	0.708 v.	0.886 v.	0.677 v.	0.869 v.
1.00 ma.	0.716 v.	0.884 v.	0.707 v.	0.879 v.	0.679 v.	0.881 v.
1.50 ma.	0.717 v.	0.887 v.	0.709 v.	0.879 v.	0.669 v.	0.874 v.
2.00 ma.	0.718 v.	0.890 v.	0.707 v.	0.881 v.	0.669 v.	0.876 v.
2.50 ma.	0.716 v.	0.894 v.	0.708 v.	0.881 v.	0.662 v.	0.876 v.
3.00 ma.	0.714 v.	0.897 v.	0.707 v.	0.884 v.	0.670 v.	0.876 v.
3.50 ma.	0.712 v.	0.900 v.	0.704 v.	0.887 v.	0.672 v.	0.875 v.

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# FIGURE 3c

ANODIC AND CATHODIC POLARIZATION OF ZINC  
SAMPLE A-3 (INHIBITOR - .20% ANTARON R-155)



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FIGURE 3(d)

Anodic and Cathodic Polarization of Zinc						
Sample No.				A-4		
Type of sample	Electrolyte - Potato Starch (40 mls/l gm.) with 0.20% Antarox A-403 as inhibitor					
Electrolyte Composition			24% NH <sub>4</sub> Cl ; 22.5% ZnCl <sub>2</sub> ; 53.5% H <sub>2</sub> O (Composition by weight)			
Area of zinc anode		0.785 sq.cm.		Area of zinc cathode		0.785 sq.cm.
	Tested at 70°F		Tested at 113°F		Tested at 160°F	
	O.C.V.	0.794 v.	O.C.V.	0.788 v.	O.C.V.	0.779 v.
Polarization Current	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage
0.08 ma.	0.777 v.	0.821 v.	0.754 v.	0.833 v.	0.756 v.	0.790 v.
0.16 ma.	0.764 v.	0.861 v.	0.748 v.	0.855 v.	0.740 v.	0.813 v.
0.30 ma.	0.761 v.	0.860 v.	0.748 v.	0.864 v.	0.726 v.	0.829 v.
0.50 ma.	0.759 v.	0.863 v.	0.743 v.	0.863 v.	0.720 v.	0.846 v.
1.00 ma.	0.756 v.	0.865 v.	0.743 v.	0.859 v.	0.725 v.	0.859 v.
1.50 ma.	0.750 v.	0.868 v.	0.742 v.	0.863 v.	0.722 v.	0.847 v.
2.00 ma.	0.747 v.	0.872 v.	0.739 v.	0.863 v.	0.728 v.	0.850 v.
2.50 ma.	0.744 v.	0.873 v.	0.738 v.	0.866 v.	0.724 v.	0.849 v.
3.00 ma.	0.740 v.	0.877 v.	0.736 v.	0.867 v.	0.725 v.	0.851 v.
3.50 ma.	0.737 v.	0.879 v.	0.735 v.	0.870 v.	0.723 v.	0.851 v.

**FIGURE 3b**  
**ANODIC AND CATHODIC POLARIZATION OF ZINC**  
**SAMPLE A-4 (INHIBITOR - .20% ANTAROX A-403)**

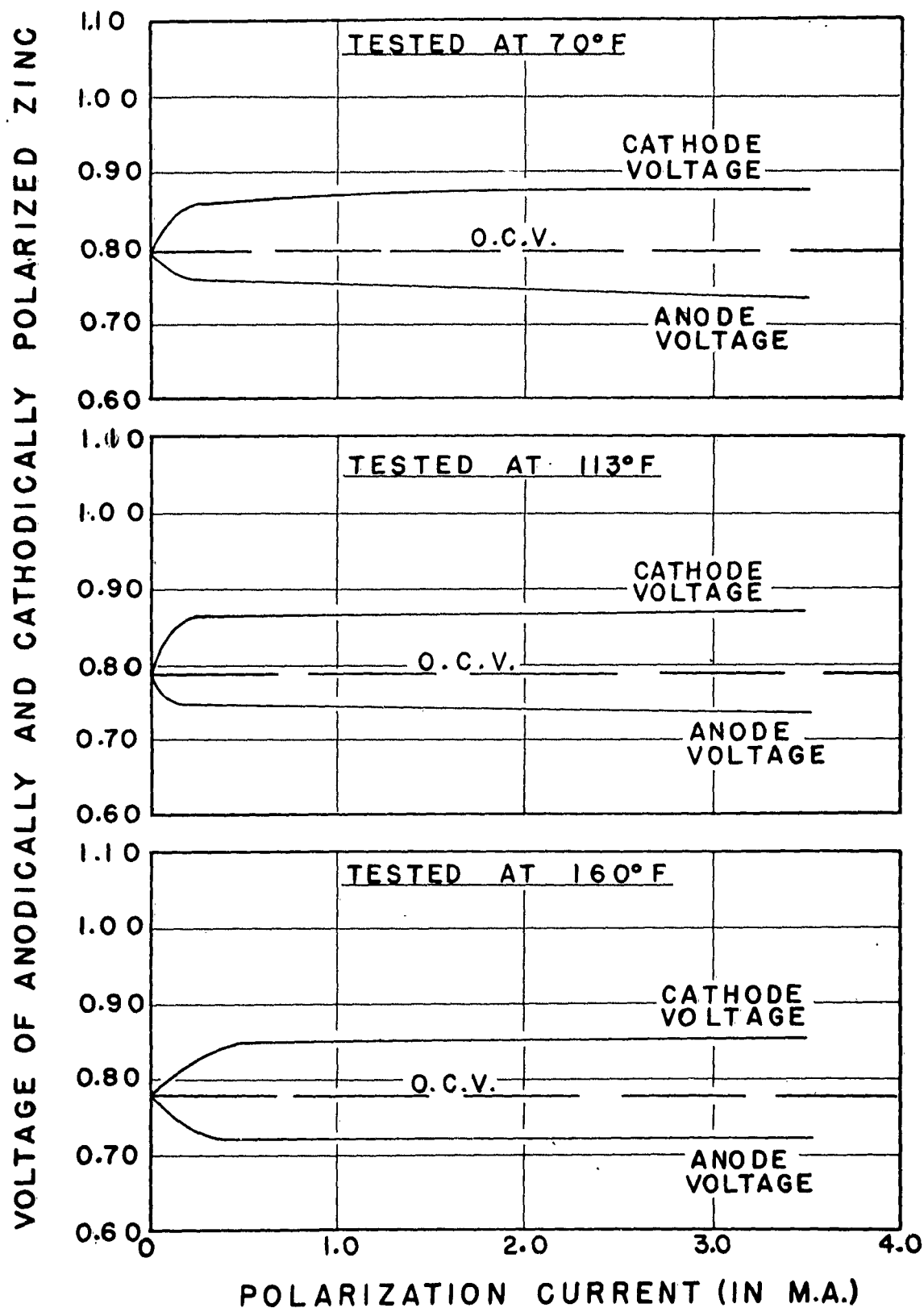


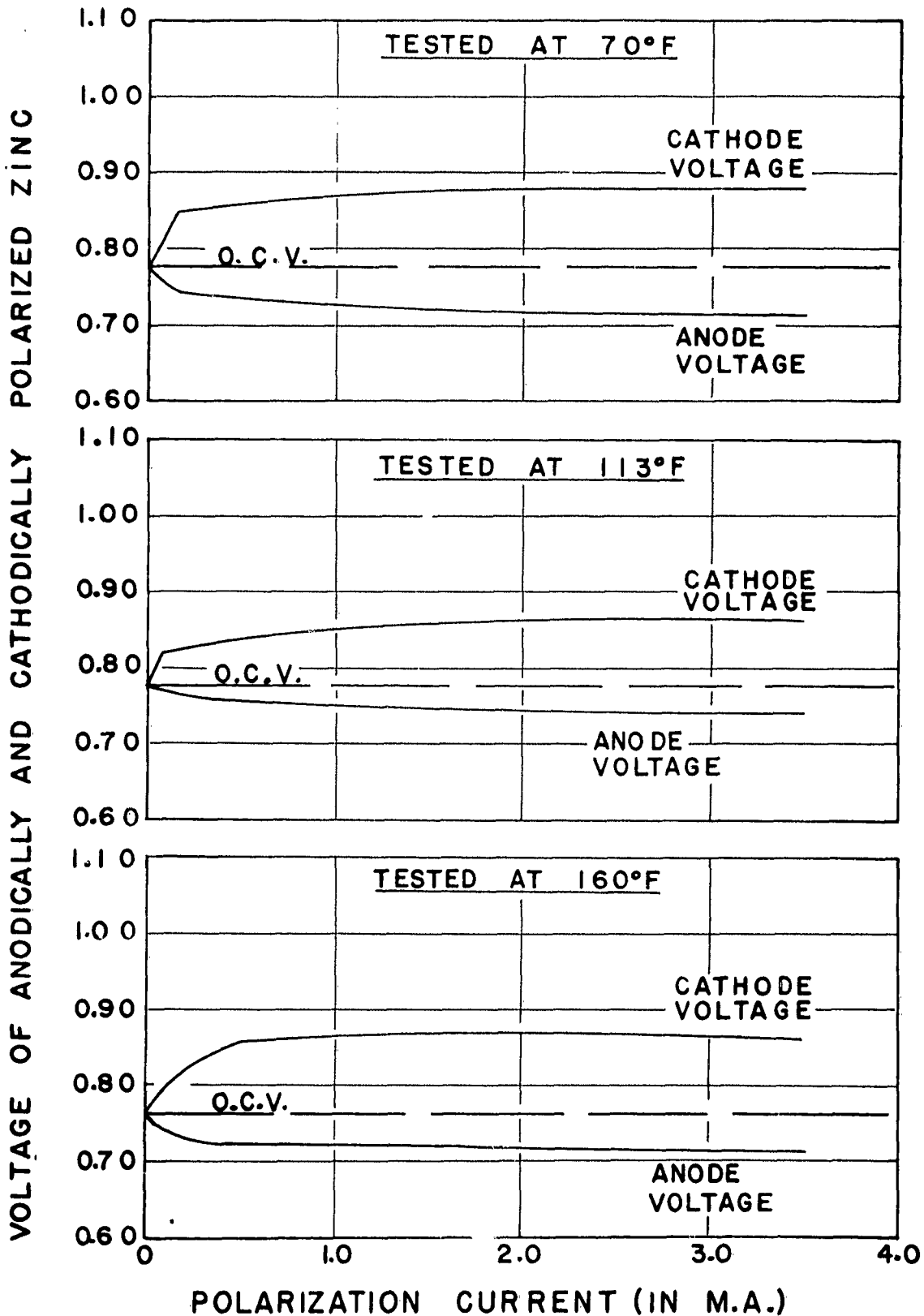
FIGURE 3(e)

Anodic and Cathodic Polarization of Zinc						
Sample No.				A-5		
Type of sample	Electrolyte - Potato Starch (40 mls/l gm.) with 1.0% Protein R2E-570 as inhibitor					
Electrolyte Composition.		24% NH <sub>4</sub> Cl ; 22.5% ZnCl <sub>2</sub> ; 53.5% H <sub>2</sub> O (Composition by weight)				
Area of zinc anode		0.785 sq.cm.		Area of zinc cathode		0.785 sq.cm.
	Tested at 70°F		Tested at 113°F		Tested at 160°F	
	O.C.V.	0.777 v.	O.C.V.	0.777 v.	O.C.V.	0.766 v.
Polarization Current	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage
0.08 ma.	0.752 v.	0.807 v.	0.772 v.	0.820 v.	0.740 v.	0.7998
0.16 ma.	0.745 v.	0.847 v.	0.766 v.	0.825 v.	0.727 v.	0.815 v.
0.30 ma.	0.745 v.	0.855 v.	0.760 v.	0.833 v.	0.730 v.	0.842 v.
0.50 ma.	0.730 v.	0.861 v.	0.756 v.	0.839 v.	0.724 v.	0.860 v.
1.00 ma.	0.730 v.	0.867 v.	0.751 v.	0.849 v.	0.722 v.	0.863 v.
1.50 ma.	0.723 v.	0.873 v.	0.749 v.	0.854 v.	0.712 v.	0.862 v.
2.00 ma.	0.721 v.	0.877 v.	0.746 v.	0.856 v.	0.714 v.	0.863 v.
2.50 ma.	0.717 v.	0.878 v.	0.744 v.	0.860 v.	0.714 v.	0.858 v.
3.00 ma.	0.715 v.	0.882 v.	0.741 v.	0.863 v.	0.715 v.	0.857 v.
3.50 ma.	0.712 v.	0.881 v.	0.739 v.	0.866 v.	0.711 v.	0.855 v.

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# FIGURE 3e

ANODIC AND CATHODIC POLARIZATION OF ZINC  
SAMPLE A-5 (INHIBITOR - 1.0% PROTEIN R2E-570)



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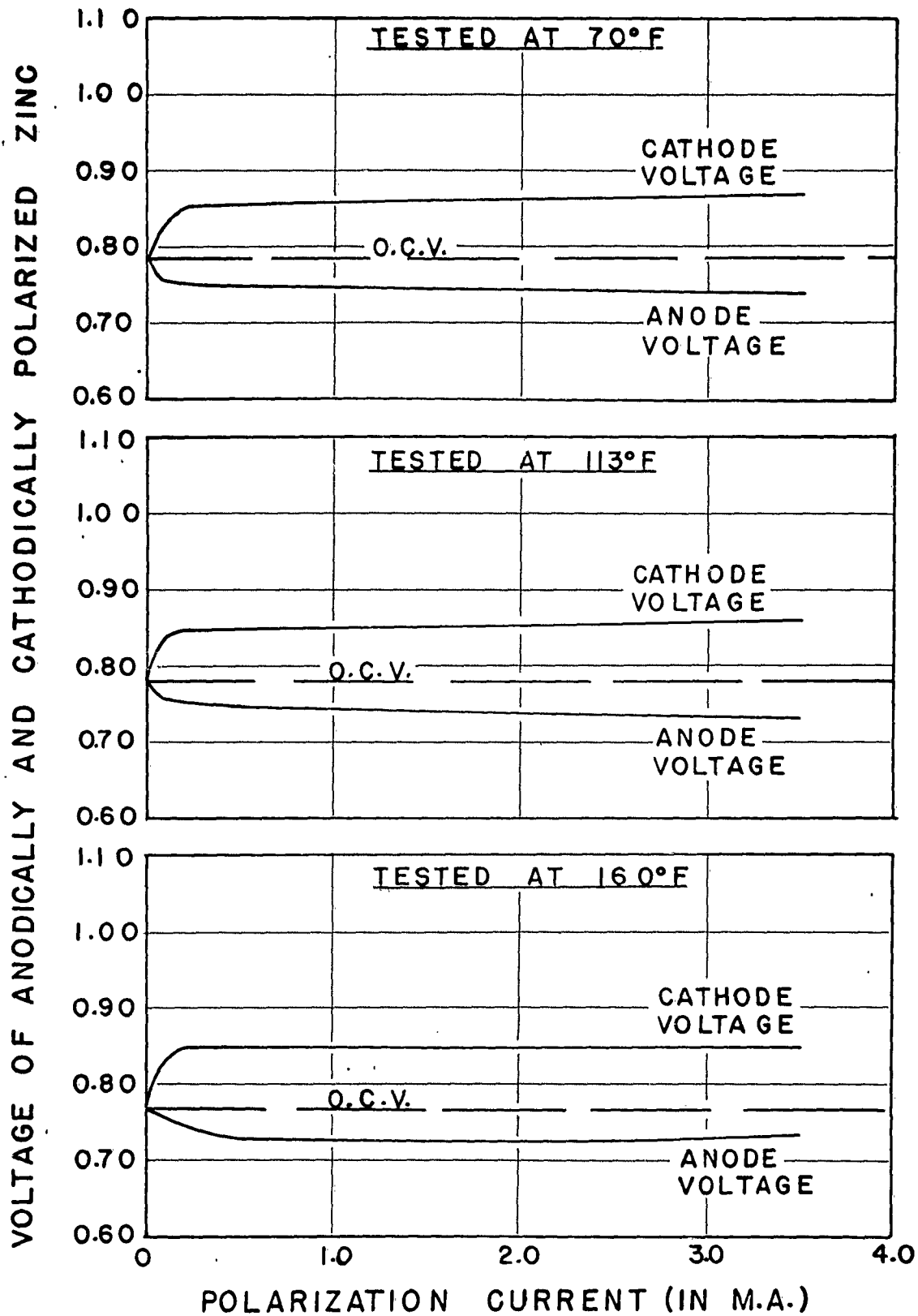
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FIGURE 3(f)

Anodic and Cathodic Polarization of Zinc						
Sample No.				A-6		
Type of sample	Electrolyte - Potato Starch (40 mls/1 gm.) with 1.0% Denatured Gluten as inhibitor					
Electrolyte Composition			24% NH <sub>4</sub> Cl ; 22.5% ZnCl <sub>2</sub> ; 53.5% H <sub>2</sub> O (Composition by weight)			
Area of zinc anode		0.785 sq.cm.		Area of zinc cathode		0.785 sq.cm.
	Tested at 70°F		Tested at 113°F		Tested at 160°F	
	O.C.V.	0.784 v.	O.C.V.	0.780 v.	O.C.V.	0.768 v.
Polarization Current	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage
0.08 ma.	0.759 v.	0.807 v.	0.758 v.	0.841 v.	0.757 v.	0.826 v.
0.16 ma.	0.755 v.	0.853 v.	0.754 v.	0.846 v.	0.749 v.	0.845 v.
0.30 ma.	0.754 v.	0.856 v.	0.753 v.	0.847 v.	0.740 v.	0.850 v.
0.50 ma.	0.750 v.	0.857 v.	0.745 v.	0.847 v.	0.729 v.	0.844 v.
1.00 ma.	0.747 v.	0.859 v.	0.746 v.	0.849 v.	0.729 v.	0.849 v.
1.50 ma.	0.746 v.	0.862 v.	0.743 v.	0.853 v.	0.728 v.	0.845 v.
2.00 ma.	0.743 v.	0.863 v.	0.739 v.	0.854 v.	0.737 v.	0.848 v.
2.50 ma.	0.742 v.	0.866 v.	0.738 v.	0.858 v.	0.732 v.	0.846 v.
3.00 ma.	0.740 v.	0.866 v.	0.735 v.	0.858 v.	0.736 v.	0.847 v.
3.50 ma.	0.739 v.	0.869 v.	0.734 v.	0.861 v.	0.734 v.	0.847 v.

**FIGURE 3F**

**ANODIC AND CATHODIC POLARIZATION OF ZINC  
SAMPLE A-6 (INHIBITOR—1.0% DENATURED GLUTEN)**



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FIGURE 3(g)

Anodic and Cathodic Polarization of Zinc						
Sample No.				A-9		
Type of sample	Electrolyte - Potato Starch (40 mls/1 gm.) with 0.20% Hg in zinc plus 0.20% antaron R-155 as inhibitors					
Electrolyte Composition			24% NH <sub>4</sub> Cl ; 22.5% ZnCl <sub>2</sub> ; 53.5% H <sub>2</sub> O (Composition by weight)			
Area of zinc anode		0.785 sq. cm.		Area of zinc cathode		0.785 sq. cm.
	Tested at 70°F		Tested at 113°F		Tested at 160°F	
	O.C.V.	0.797 v.	O.C.V.	0.789 v.	O.C.V.	0.774 v.
Polarization Current	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage
0.08 ma.	0.791 v.	0.821 v.	0.773 v.	0.797 v.	0.765 v.	0.774 v.
0.16 ma.	0.758 v.	0.841 v.	0.762 v.	0.804 v.	0.762 v.	0.797 v.
0.30 ma.	0.743 v.	0.866 v.	0.743 v.	0.826 v.	0.754 v.	0.813 v.
0.50 ma.	0.737 v.	0.890 v.	0.727 v.	0.850 v.	0.744 v.	0.833 v.
1.00 ma.	0.706 v.	0.901 v.	0.702 v.	0.883 v.	0.725 v.	0.859 v.
1.50 ma.	0.693 v.	0.897 v.	0.686 v.	0.884 v.	0.715 v.	0.876 v.
2.00 ma.	0.683 v.	0.897 v.	0.674 v.	0.887 v.	0.706 v.	0.878 v.
2.50 ma.	0.674 v.	0.900 v.	0.665 v.	0.888 v.	0.700 v.	0.886 v.
3.00 ma.	0.666 v.	0.902 v.	0.657 v.	0.889 v.	0.693 v.	0.886 v.
3.50 ma.	0.659 v.	0.904 v.	0.650 v.	0.892 v.	0.689 v.	0.888 v.

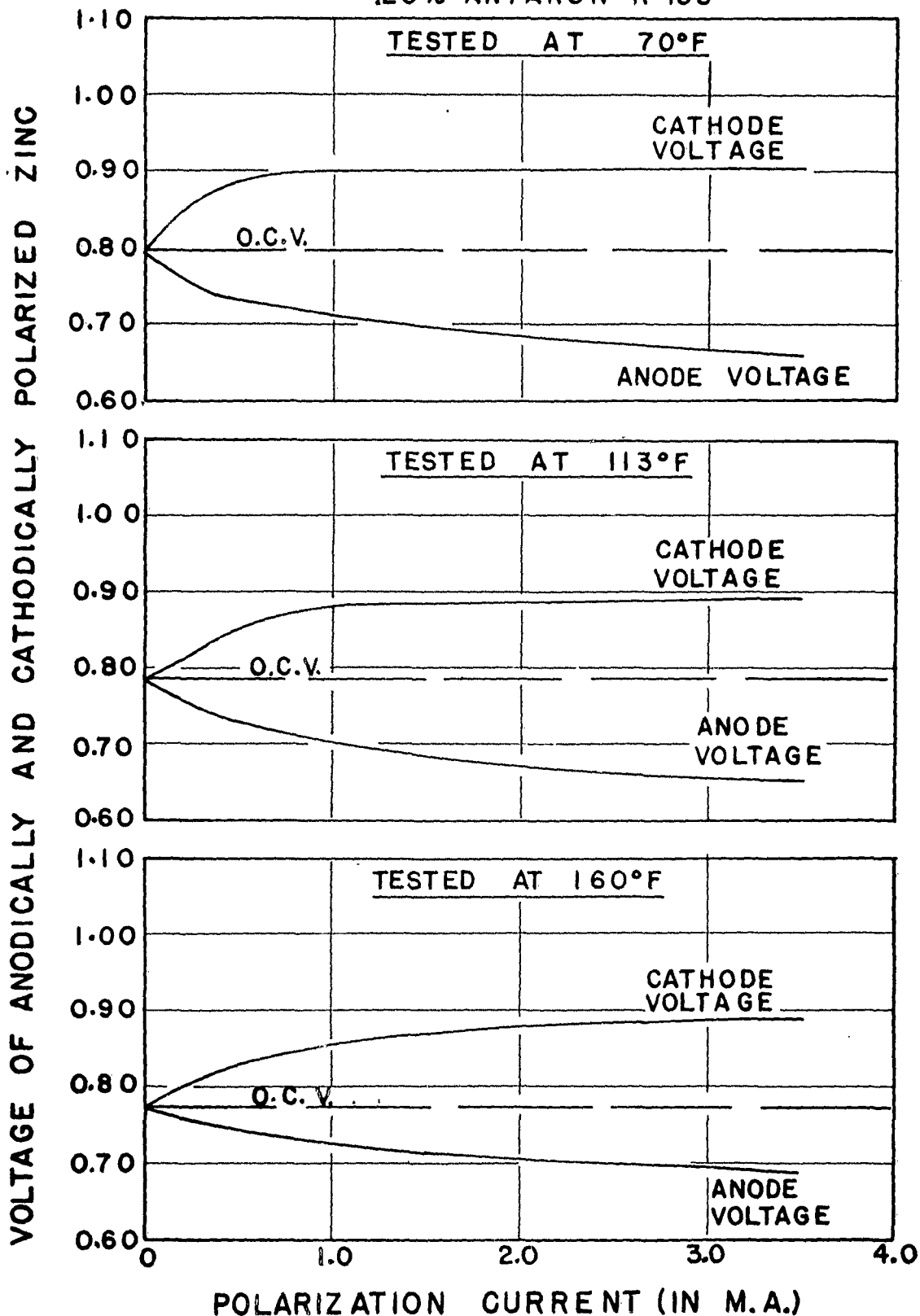
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# FIGURE 3c

## ANODIC AND CATHODIC POLARIZATION OF ZINC

SAMPLE A-9 (INHIBITOR - .20% Hg IN ZN +  
.20% ANTARON R-155



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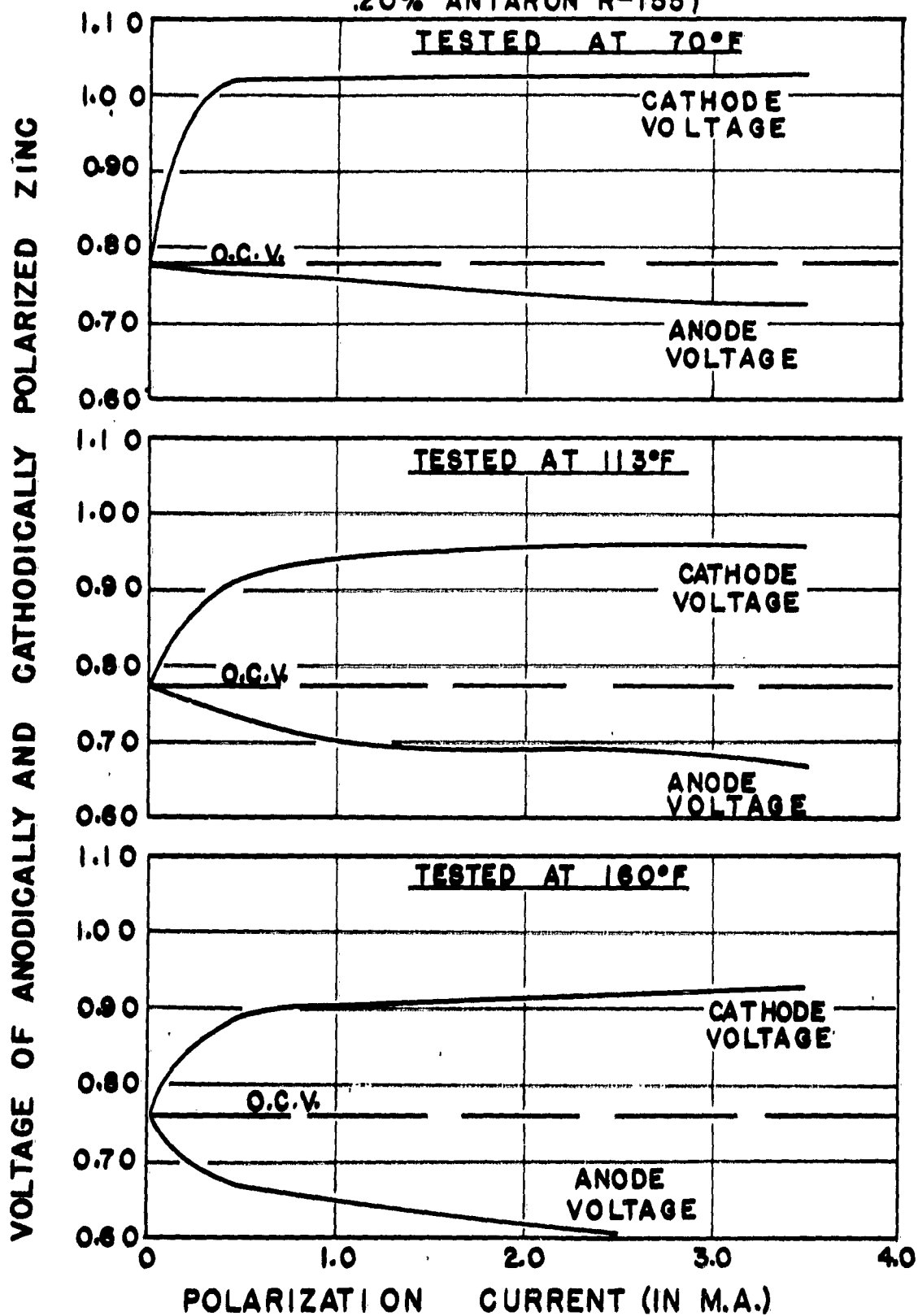
FIGURE 3(h)

Anodic and Cathodic Polarization of Zinc						
Sample No.				A-10		
Type of sample	Electrolyte - Potato Starch (40 mls/1 gm.) with 0.20% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> plus 0.20% Antaron R-155 as inhibitors					
Electrolyte Composition			24% NH <sub>4</sub> Cl ; 22.5% ZnCl <sub>2</sub> ; 53.5% H <sub>2</sub> O (Composition by weight)			
Area of zinc anode		0.785 sq.cm.		Area of zinc cathode		0.785 sq.cm.
	Tested at 70°F		Tested at 113°F		Tested at 160°F	
	O.C.V.	0.780 v.	O.C.V.	0.775 v.	O.C.V.	0.761 v.
Polarization Current	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage
0.08 ma.	0.775 v.	0.880 v.	0.768 v.	0.821 v.	0.723 v.	0.802 v.
0.16 ma.	0.774 v.	0.927 v.	0.763 v.	0.855 v.	0.709 v.	0.832 v.
0.30 ma.	0.768 v.	0.999 v.	0.744 v.	0.882 v.	0.692 v.	0.864 v.
0.50 ma.	0.767 v.	1.025 v.	0.736 v.	0.920 v.	0.666 v.	0.892 v.
1.00 ma.	0.759 v.	1.018 v.	0.701 v.	0.947 v.	0.648 v.	0.902 v.
1.50 ma.	0.748 v.	1.027 v.	0.689 v.	0.946 v.	0.628 v.	0.910 v.
2.00 ma.	0.739 v.	1.032 v.	0.692 v.	0.950 v.	0.617 v.	0.919 v.
2.50 ma.	0.732 v.	1.035 v.	0.688 v.	0.953 v.	0.603 v.	0.924 v.
3.00 ma.	0.730 v.	1.037 v.	0.679 v.	0.955 v.	0.596 v.	0.926 v.
3.50 ma.	0.725 v.	1.036 v.	0.670 v.	0.960 v.	0.589 v.	0.929 v.

## FIGURE 3H

## ANODIC AND CATHODIC POLARIZATION OF ZINC

SAMPLE A-10 (INHIBITOR - .20%  $\text{Na}_2\text{Cr}_2\text{O}_7$  +  
.20% ANTARON R-155)



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FIGURE 3(1)

Anode and Cathodic Polarization of Zinc

Sample No.				A - 13		
Type of sample	Electrolyte - Potato Starch (40 mls/1 gm) Inhibitor - 0.1% Quinaldine					
Electrolyte Composition			24.0% NH <sub>4</sub> Cl ; 22.5% ZnCl <sub>2</sub> ; 53.5% H <sub>2</sub> O (Composition by weight)			
Area of Zinc Anode		0.785 sq.cm.		Area of Zinc Cathode		0.785 sq.cm.
	Tested at 70°F		Tested at 113°F		Tested at 160°F	
	O.C.V.	0.736 v.	O.C.V.	0.734 v.	O.C.V.	0.741 v.
Polarization Current	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage
0.08 ma.	0.714 v.	0.907 v.	0.715 v.	0.858 v.	0.711 v.	0.842 v.
0.16 ma.	0.716 v.	0.950 v.	0.724 v.	0.894 v.	0.728 v.	0.864 v.
0.30 ma.	0.713 v.	1.077 v.	0.714 v.	0.901 v.	0.706 v.	0.884 v.
0.50 ma.	0.714 v.	1.058 v.	0.715 v.	0.904 v.	0.711 v.	0.898 v.
1.00 ma.	0.711 v.	1.068 v.	0.710 v.	0.913 v.	0.700 v.	0.885 v.
1.50 ma.	0.712 v.	1.078 v.	0.711v.	0.922 v.	0.707 v.	0.898 v.
2.00 ma.	0.709 v.	1.073 v.	0.709 v.	0.926 v.	0.704 v.	0.891 v.
2.50 ma.	0.713 v.	1.064 v.	0.709 v.	0.931 v.	0.704 v.	0.895 v.
3.00 ma.	0.711 v.	1.058 v.	0.710 v.	1.012 v.	0.701 v.	0.895 v.
3.50 ma.	0.710 v.	1.068 v.	0.710 v.	1.032 v.	0.702 v.	0.900 v.

FIGURE 3(1)Cont.  
ANODIC AND CATHODIC POLARIZATION OF ZINC  
Inhibitor - 0.1% Quinaldine

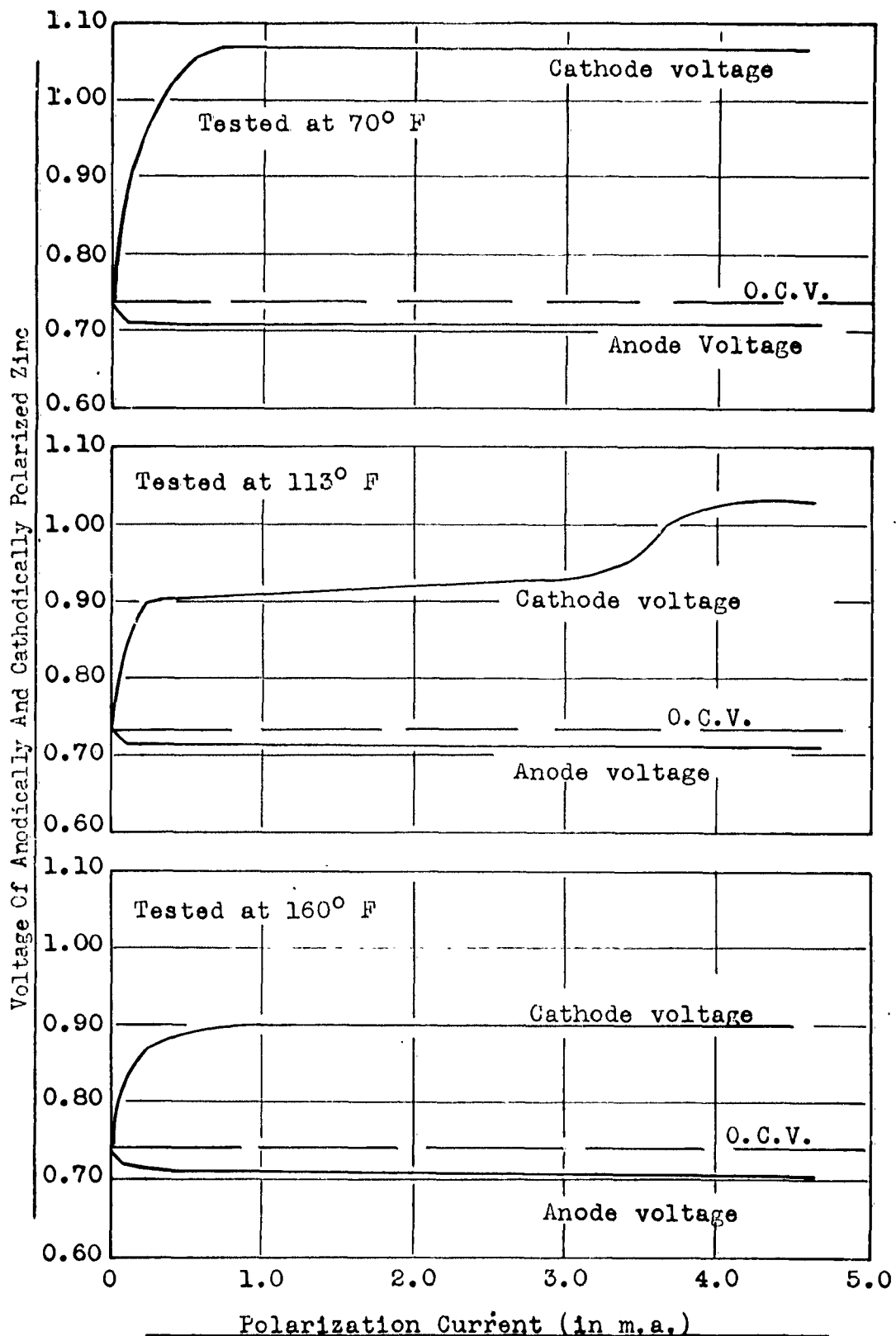


FIGURE 4

ANODIC POLARIZATION OF ZINC VS TIME  
AT A CONSTANT CURRENT DENSITY OF 4.33 MA./SQ. CM.

(TESTED AT 113° F.)

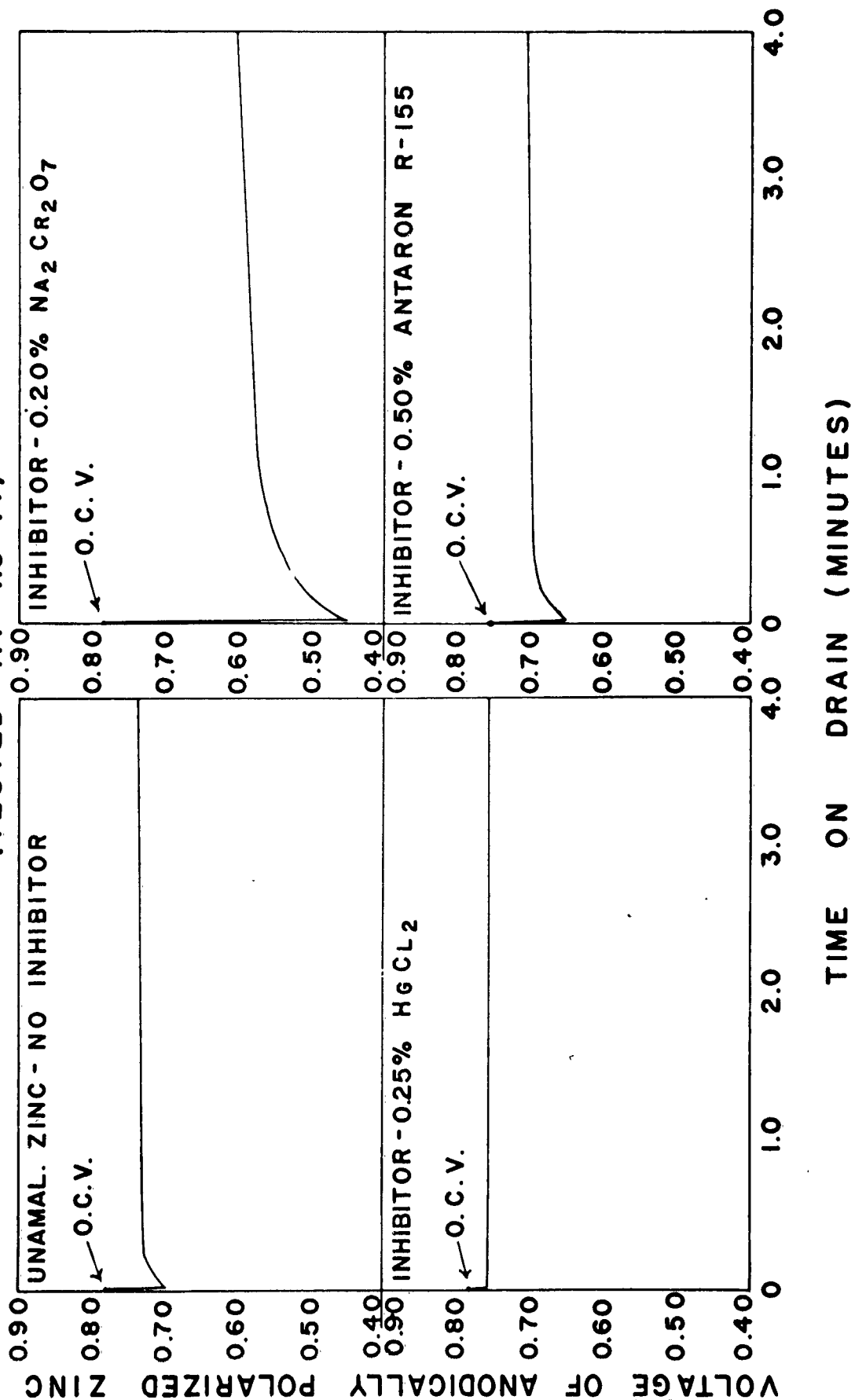


FIGURE 4 (Cont.)

ANODIC AND CATHODIC POLARIZATION OF ZINC  
(TESTED AT 70°F)

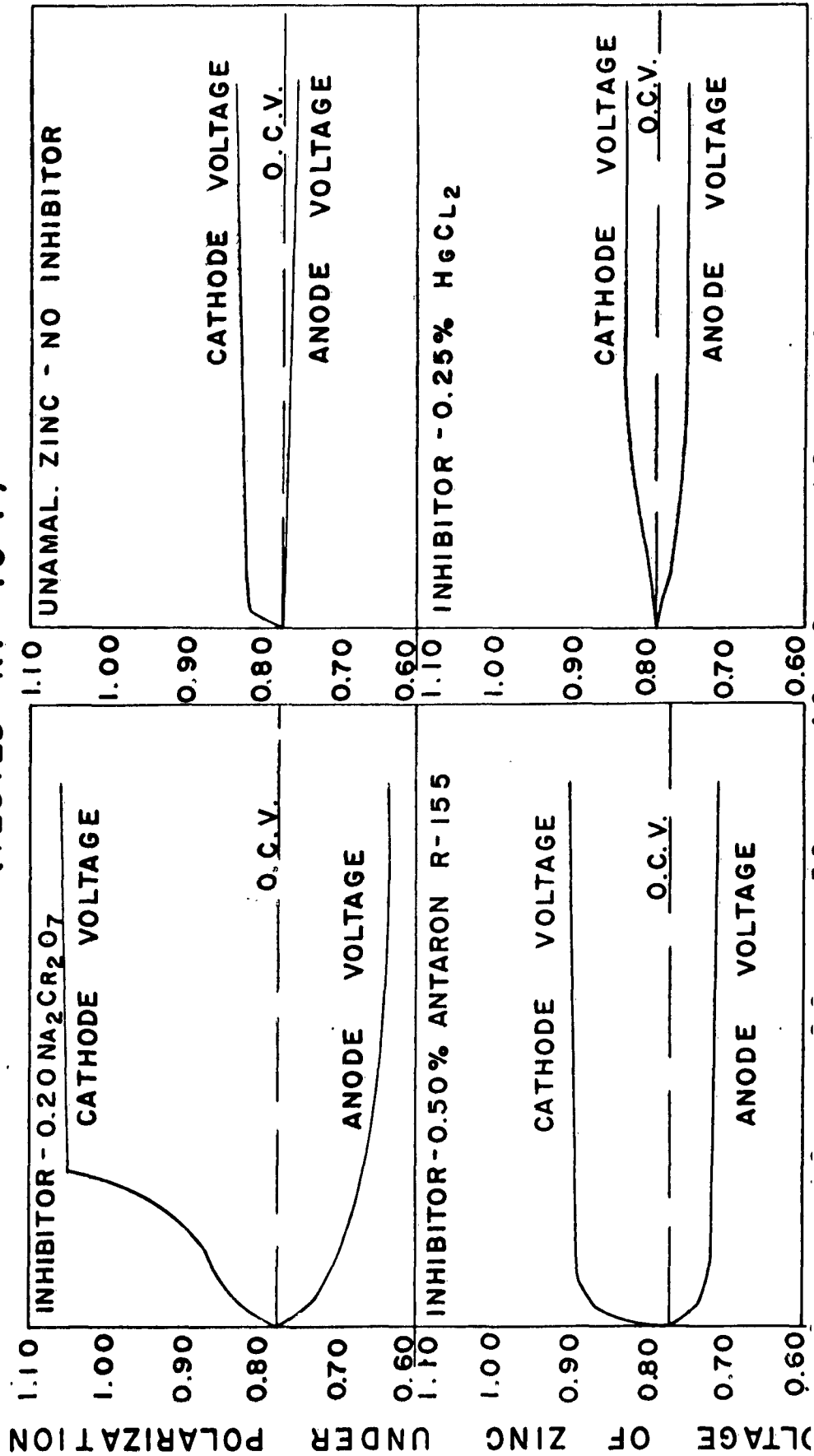
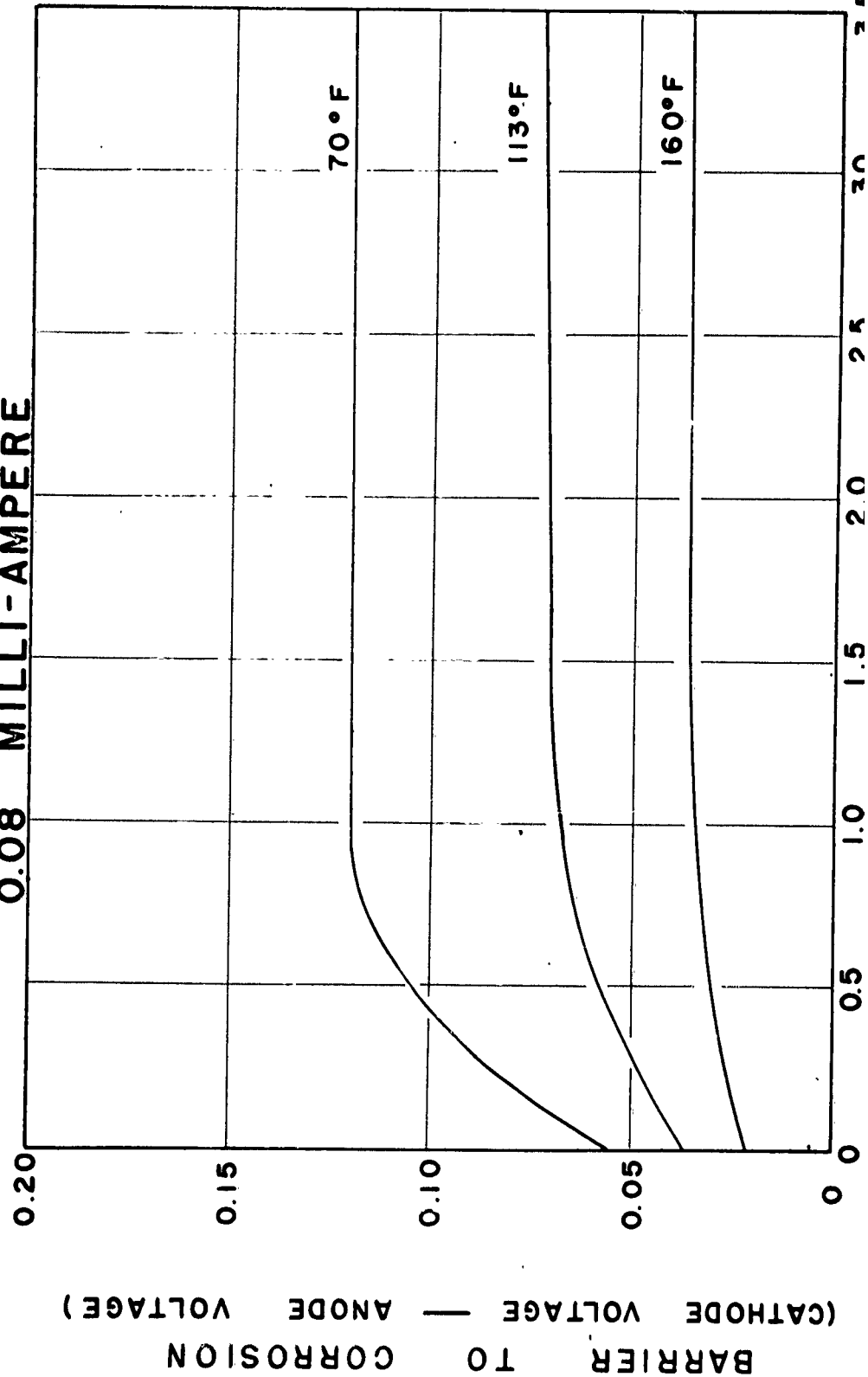


FIGURE 5

EFFECT OF CHROME CONCENTRATION ON THE CORROSION  
BARRIER AT A CONSTANT CURRENT DENSITY OF  
0.08 MILLI-AMPERE



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FIGURE 6

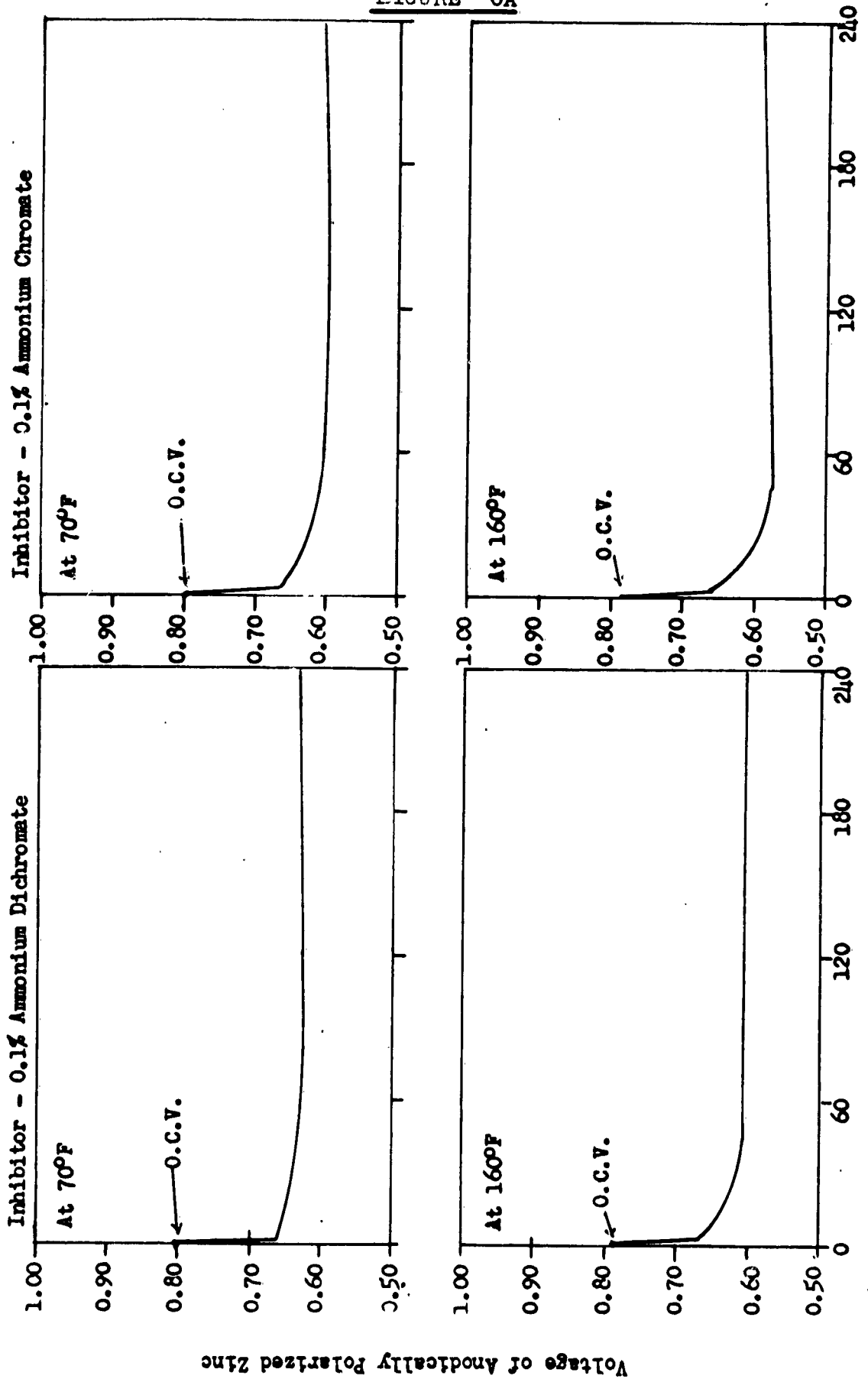
ANODIC POLARIZATION				
Anodic Polarization Current Density			4.33 ma./sq.cm.	
Inhibitor	0.1% (NH <sub>4</sub> ) <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>		0.1% (NH <sub>4</sub> ) <sub>2</sub> CrO <sub>4</sub>	
	After 24 hrs at 70°F	After 24 hrs at 160°F	After 24 hrs at 70°F	After 24 hrs at 160°F
O.C.V. before polarization	0.798 v.	0.784 v.	0.795 v.	0.785 v.
Time polarized	Anodic Voltage			
1 second	0.658 v.	0.668 v.	0.663 v.	0.658 v.
15 seconds	0.653 v.	0.632 v.	0.645 v.	0.623 v.
30 seconds	0.634 v.	0.616 v.	0.623 v.	0.587 v.
60 seconds	0.626 v.	0.606 v.	0.603 v.	0.577 v.
90 seconds	0.624 v.	0.603 v.	0.595 v.	0.579 v.
120 seconds	0.628 v.	0.604 v.	0.595 v.	0.582 v.
180 seconds	0.630 v.	0.606 v.	0.598 v.	0.589 v.
240 seconds	0.632 v.	0.608 v.	0.603 v.	0.591 v.

CATHODIC AND ANODIC POLARIZATION								
Inhibitor	0.1% (NH <sub>4</sub> ) <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>				0.1% (NH <sub>4</sub> ) <sub>2</sub> CrO <sub>4</sub>			
	Tested @ 70°F		Tested @ 160°F		Tested @ 70°F		Tested @ 160°F	
	OCV - 0.796 v.		OCV - 0.778 v.		OCV - 0.795 v.		OCV - 0.786 v.	
Polarization Current	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage
0.01 ma.	0.789	0.802	0.776	0.781	0.791	0.814	0.784	0.790
0.029 ma.	0.780	0.814	0.770	0.784	0.786	0.832	0.780	0.797
0.035 ma.	0.779	0.821	0.768	0.787	0.786	0.840	0.779	0.804
0.046 ma.	0.777	0.837	0.760	0.789	0.786	0.845	0.776	0.809
0.075 ma.	0.772	0.838	0.750	0.798	0.782	0.852	0.772	0.822
0.100 ma.	0.769	0.844	0.739	0.802	0.782	0.857	0.765	0.829
0.150 ma.	0.764	0.850	0.728	0.817	0.781	0.863	0.755	0.843
0.300 ma.	0.750	0.862	0.703	0.830	0.778	0.878	0.736	0.854

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FIGURE 6A

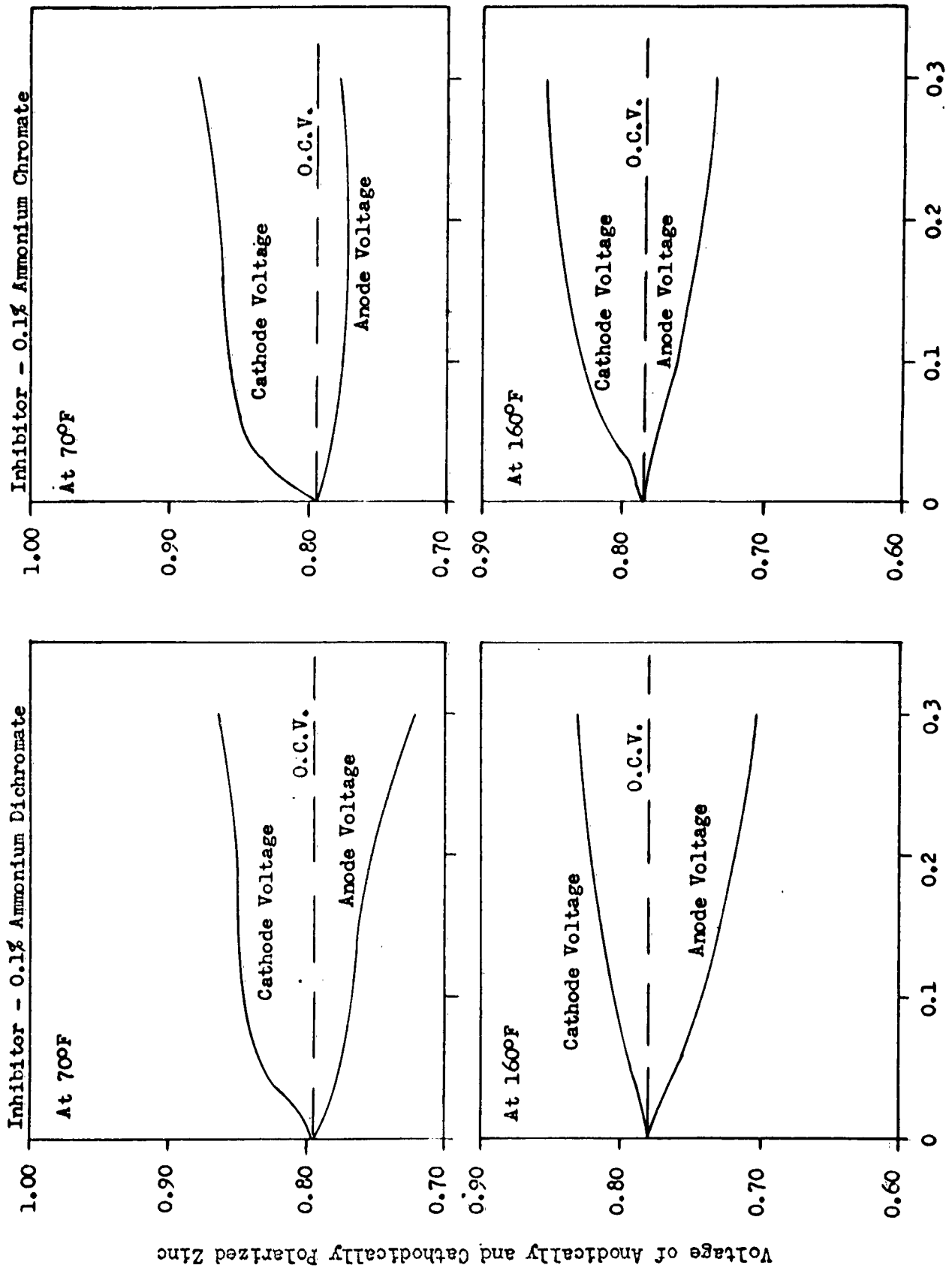
Anodic Polarisation Of Zinc



Time on Polarization (in seconds)

FIGURE 6B

Cathodic and Anodic Polarization of Zinc  
Effect of Ammonium Dichromate vs. Effect of Ammonium Chromate



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FIGURE 6 (Cont.)

ANODIC POLARIZATION				
Anodic polarization current density			4.33 ma./sq.cm.	
Inhibitor	1.0% (NH <sub>4</sub> ) <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>		1.0% (NH <sub>4</sub> ) <sub>2</sub> CrO <sub>4</sub>	
	After 24 hrs at 70°F	After 24 hrs at 160°F	After 24 hrs. at 70°F	After 24 hrs. at 160°F
O.C.V. before polarization	0.789 v.	0.694 v.	0.793 v.	0.789 v.
Time polarized	Anodic Voltage			
1 second	0.578 v.	0.548 v.	0.683 v.	0.688 v.
15 "	0.621 v.	0.556 v.	0.714 v.	0.623 v.
30 "	0.668 v.	0.576 v.	0.724 v.	0.614 v.
60 "	0.714 v.	0.597 v.	0.732 v.	0.617 v.
90 "	0.724 v.	0.611 v.	0.734 v.	0.618 v.
120 "	0.729 v.	0.621 v.	0.737 v.	0.617 v.
180 "	0.733 v.	0.640 v.	0.739 v.	0.611 v.
240 "	0.736 v.	0.657 v.	0.739 v.	0.605 v.

CATHODIC AND ANODIC POLARIZATION								
Inhibitor	1.0% (NH <sub>4</sub> ) <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>				1.0% (NH <sub>4</sub> ) <sub>2</sub> CrO <sub>4</sub>			
	Tested @ 70°F		Tested @ 160°F		Tested @ 70°F		Tested @ 160°F	
	OCV - 0.795 v.		OCV - 0.753 v.		OCV - 0.798 v.		OCV - 0.779 v.	
Polarization Current	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage
0.01 ma.	0.790	0.801	0.741	0.763	0.792	0.807	0.776	0.784
0.029 ma.	0.778	0.810	0.728	0.768	0.791	0.821	0.767	0.790
0.035 ma.	0.773	0.819	0.726	0.776	0.790	0.842	0.764	0.799
0.046 ma.	0.768	0.825	0.718	0.780	0.791	0.850	0.751	0.803
0.075 ma.	0.763	0.836	0.712	0.790	0.788	0.887	0.744	0.822
0.100 ma.	0.753	0.843	0.701	0.796	0.787	0.915	0.725	0.830
0.150 ma.	0.745	0.860	0.692	0.811	0.785	0.945	0.713	0.846
0.300 ma.	0.721	0.884	0.671	0.826	0.782	0.977	0.671	0.862

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FIGURE 6A (Cont.)

ANODIC POLARIZATION OF ZINC

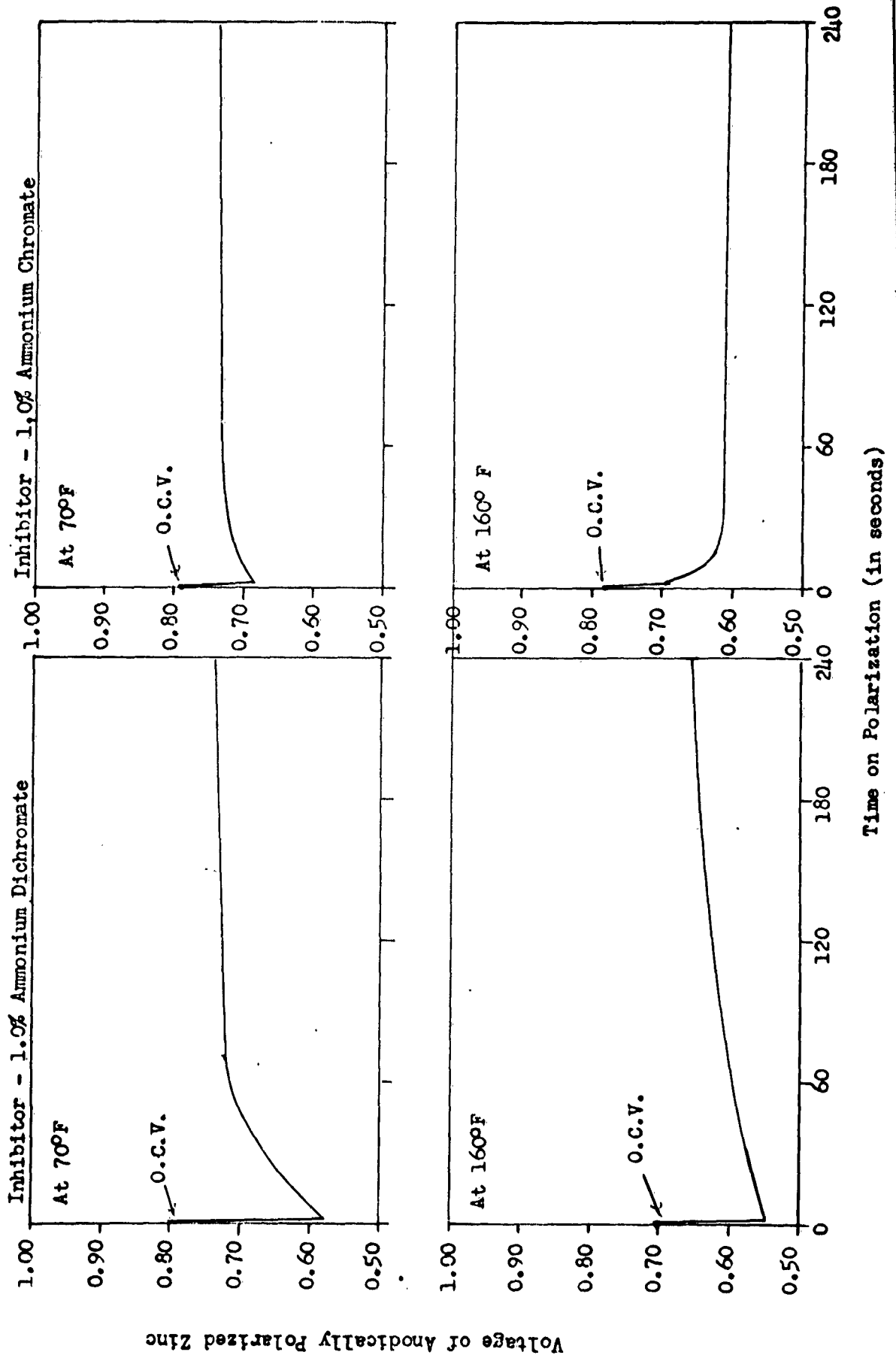
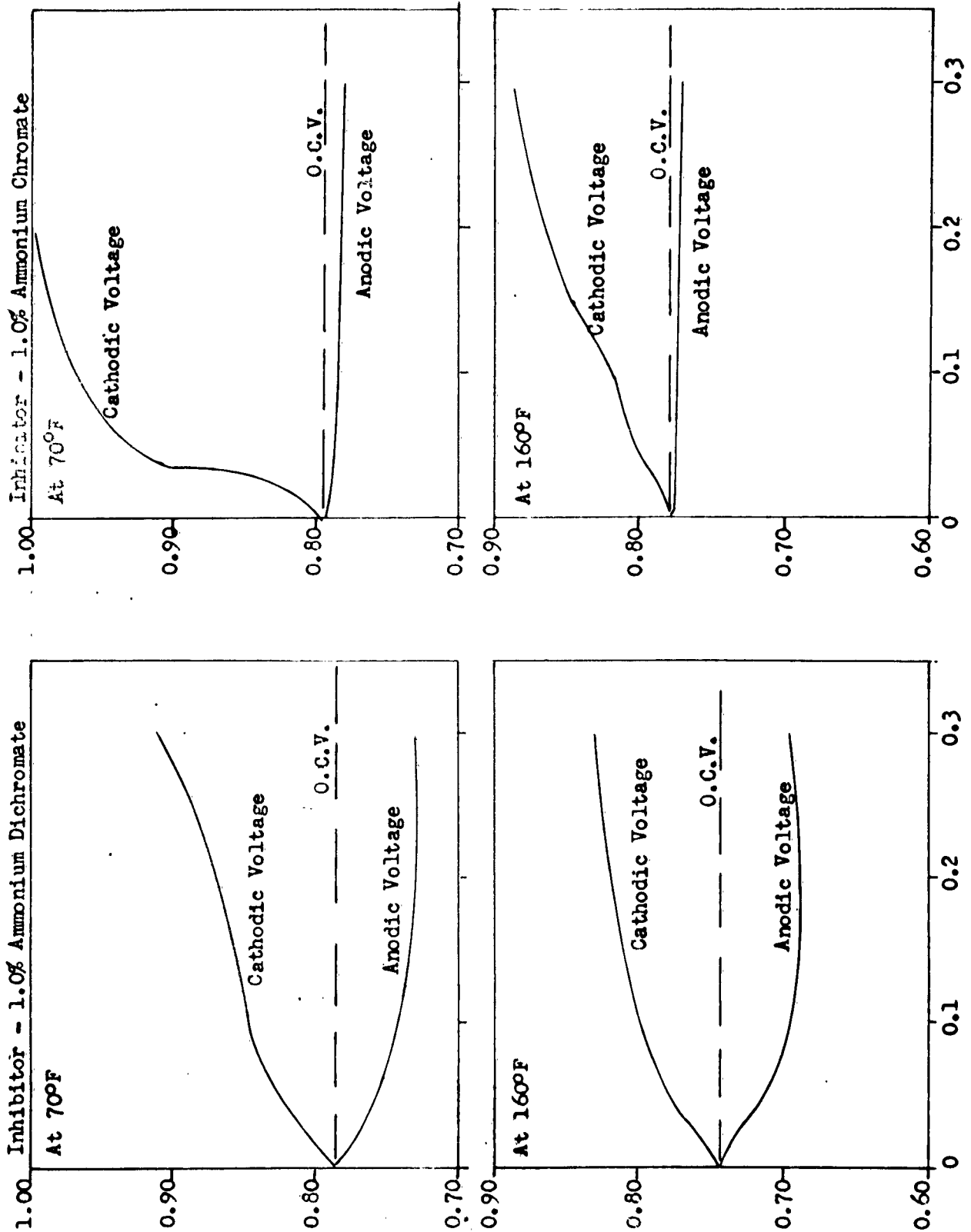


FIGURE 6B (Cont.)

ANODIC AND CATHODIC POLARIZATION OF ZINC  
Effect of Ammonium Dichromate vs. Effect of Ammonium Chromate



Voltage of Anodically and Cathodically Polarized Zinc

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Current Drain per 0.785 sq. cm. of Zinc (in milliamperes)

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FIGURE 6 (Cont.)

ANODIC POLARIZATION				
Anodic Polarization Current Density			4.33 ma./sq.cm.	
Inhibitor	3.0% (NH <sub>4</sub> ) <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>		3.0% (NH <sub>4</sub> ) <sub>2</sub> CrO <sub>4</sub>	
	After 24 hr at 70°F	After 24 hrs at 160°F	After 24 hrs at 70°F	After 24 hrs at 160°F
O.C.V. before polarization	0.772 v.	0.754 v.	0.795 v.	0.789 v.
Time polarized	Anodic Voltage			
1 second	0.558 v.	0.578 v.	0.698 v.	0.718 v.
15 "	0.713 v.	0.678 v.	0.724 v.	0.732 v.
30 "	0.731 v.	0.711 v.	0.726 v.	0.735 v.
60 "	0.742 v.	0.725 v.	0.730 v.	0.734 v.
90 "	0.747 v.	0.728 v.	0.731 v.	0.731 v.
120 "	0.750 v.	0.729 v.	0.730 v.	0.728 v.
180 "	0.754 v.	0.729 v.	0.729 v.	0.721 v.
240 "	0.756 v.	0.729 v.	0.728 v.	0.716 v.

CATHODIC AND ANODIC POLARIZATION								
Inhibitor	3.0% (NH <sub>4</sub> ) <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>				3.0% (NH <sub>4</sub> ) <sub>2</sub> CrO <sub>4</sub>			
	Tested @ 70°F		Tested @ 160°F		Tested @ 70°F		Tested @ 160°F	
	OCV - 0.788 v.		OCV - 0.756 v.		OCV - 0.796 v.		OCV - 0.783 v.	
Polarization Current	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage
0.01 ma	0.780	0.794	0.756	0.760	0.790	0.812	0.783	0.788
0.029 ma.	0.769	0.806	0.752	0.767	0.788	0.829	0.782	0.796
0.035 ma.	0.760	0.812	0.750	0.775	0.786	0.864	0.781	0.802
0.046 ma.	0.754	0.825	0.740	0.779	0.787	0.927	0.782	0.807
0.075 ma.	0.742	0.835	0.728	0.796	0.785	0.955	0.779	0.825
0.100 ma.	0.735	0.856	0.707	0.804	0.783	0.974	0.780	0.840
0.150 ma.	0.725	0.876	0.697	0.821	0.782	0.993	0.777	0.892
0.300 ma.	0.708	0.932	0.691	0.840	0.778	1.029	0.775	0.934

FIGURE 6A (Cont.)

ANODIC POLARIZATION OF ZINC

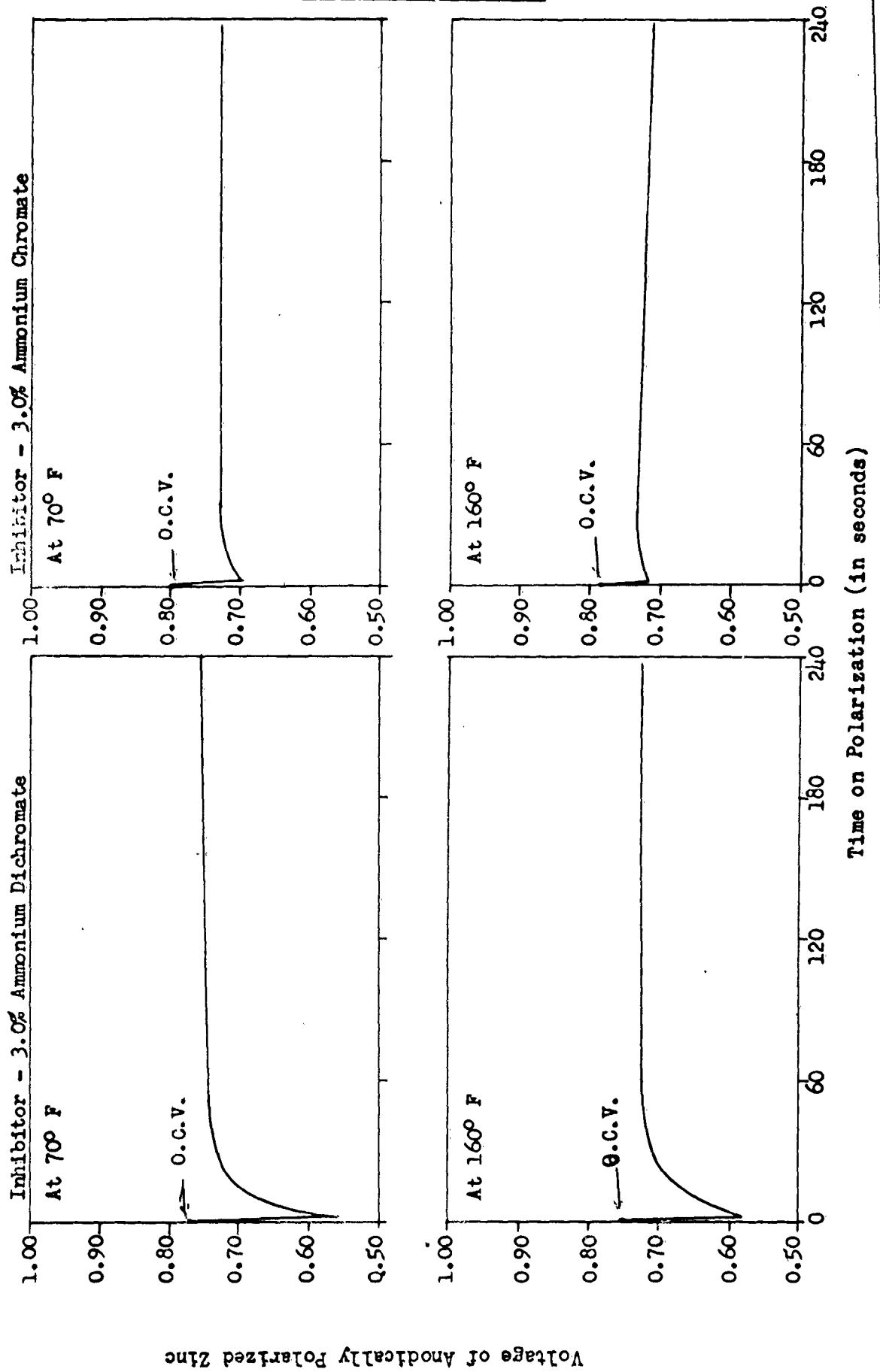
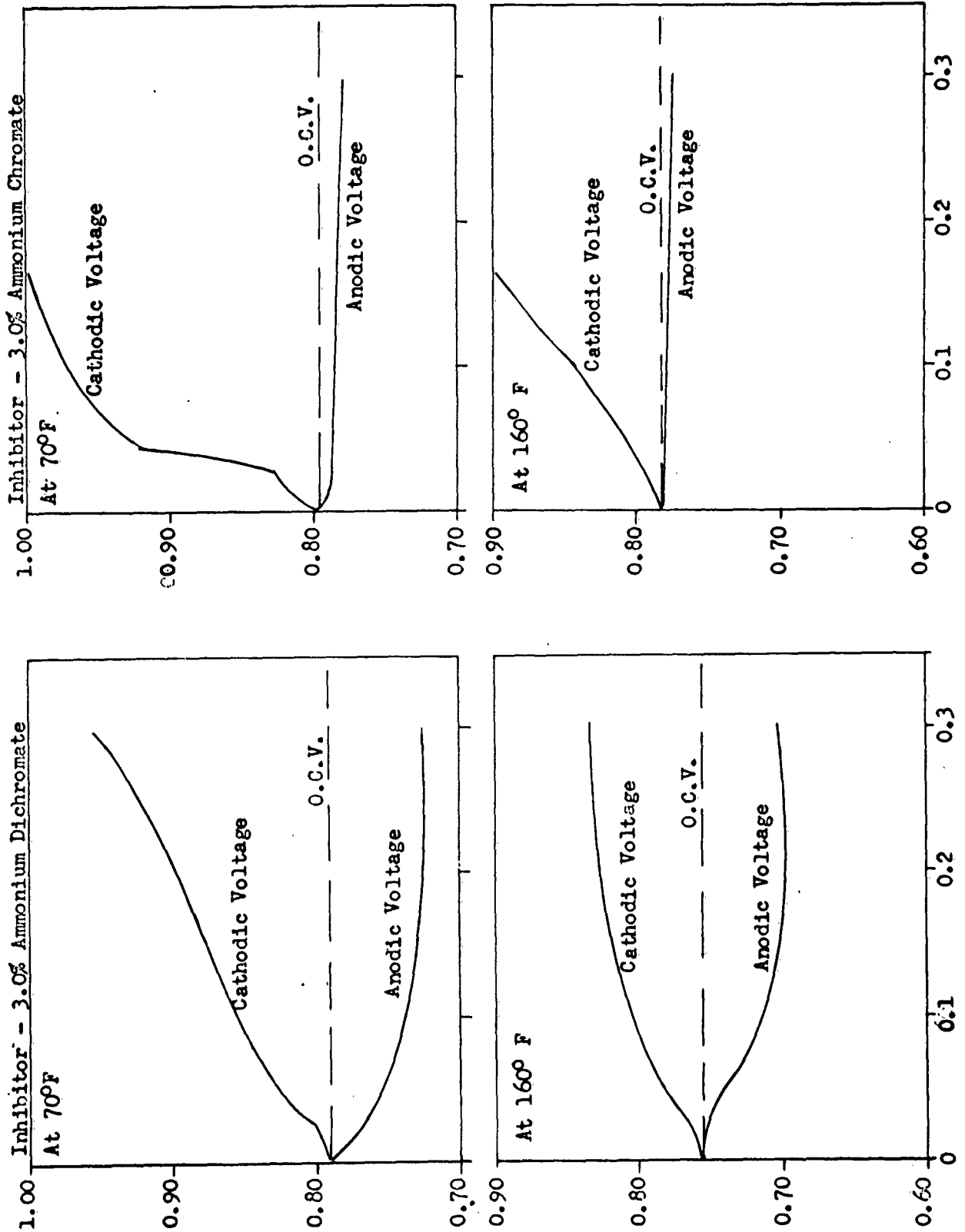


FIGURE 6B (Cont.)

ANODIC AND CATHODIC POLARIZATION OF ZINC  
Effect of Ammonium Dichromate vs. Effect of Ammonium Chromate



Voltage of Anodically and Cathodically Polarized zinc

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FIGURE 7

ANODIC POLARIZATION				
Anodic Polarization Current Density			4.33 ma./sq.cm.	
Inhibitor	0.25% Hg in Zn		0.25% Hg in Zn + 0.2% AmCr	
	After 24 hrs at 70°F	After 24 hrs at 130°F	After 24 hrs at 70°F	After 24 hrs at 130°F
O.C.V. before polarization	0.807 v.	0.801 v.	0.797 v.	0.799 v.
Time polarized	Anodic Voltage			
1 second.	0.778 v.	0.797 v.	0.658 v.	0.658 v.
15 "	0.778 v.	0.779 v.	0.692 v.	0.624 v.
30 "	0.777 v.	0.777 v.	0.678 v.	0.621 v.
60 "	0.774 v.	0.778 v.	0.705 v.	0.622 v.
90 "	0.773 v.	0.778 v.	0.709 v.	0.625 v.
120 "	0.774 v.	0.778 v.	0.711 v.	0.628 v.
180 "	0.776 v.	0.777 v.	0.719 v.	0.634 v.
240 "	0.776 v.	0.777 v.	0.721 v.	0.635 v.

CATHODIC AND ANODIC POLARIZATION								
Inhibitor	0.25% Hg in Zn				0.25% Hg in Zn + 0.2% AmCr			
	Tested @ 70°F		Tested @ 130°F		Tested @ 70°F		Tested @ 130°F	
	OCV - 0.808 v.		OCV - 0.804 v.		OCV - 0.800 v.		OCV - 0.797 v.	
Polarization Current	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage
0.01 ma.	0.808	0.809	0.804	0.805	0.794	0.812	0.796	0.800
0.029 ma.	0.808	0.809	0.804	0.805	0.786	0.830	0.792	0.804
0.035 ma.	0.807	0.810	0.804	0.805	0.784	0.840	0.791	0.808
0.046 ma.	0.807	0.810	0.804	0.805	0.783	0.846	0.787	0.812
0.075 ma.	0.807	0.811	0.804	0.805	0.777	0.853	0.783	0.824
0.100 ma.	0.807	0.812	0.804	0.805	0.773	0.858	0.774	0.833
0.150 ma.	0.806	0.814	0.803	0.806	0.765	0.865	0.767	0.853
0.300 ma.	0.804	0.820	0.803	0.806	0.751	0.878	0.753	0.865

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FIGURE 7 (Cont.)

ANODIC POLARIZATION				
Anodic Polarization Current Density			4.33 ma./sq.cm.	
Inhibitor	0.1% Antaron R 155		0.3% Antarox A 403	
	After 24 hrs at 70° F	After 24 hrs at 130° F	After 24 hrs at 70° F	After 24 hrs at 130° F
O.C.V. before polarization	0.754 v.	0.764 v.	0.780 v.	0.773 v.
Time polarized	Anodic Voltage			
1 second	0.628 v.	0.738 v.	0.683 v.	0.716 v.
15 "	0.646 v.	0.696 v.	0.722 v.	0.713 v.
30 "	0.662 v.	0.700 v.	0.729 v.	0.714 v.
60 "	0.681 v.	0.707 v.	0.735 v.	0.715 v.
90 "	0.688 v.	0.711 v.	0.738 v.	0.718 v.
120 "	0.694 v.	0.714 v.	0.741 v.	0.721 v.
180 "	0.701 v.	0.720 v.	0.742 v.	0.724 v.
240 "	0.705 v.	0.724 v.	0.745 v.	0.724 v.

CATHODIC AND ANODIC POLARIZATION								
Inhibitor	0.1% Antaron R 155				0.3% Antarox A 403			
	Tested @ 70°F		Tested @ 130°F		Tested @ 70°F		Tested @ 130°F	
	OCV - 0.771 v.		OCV - 0.774 v.		OCV - 0.771 v.		OCV - 0.771 v.	
Polarization Current	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage
0.01 ma.	0.754	0.807	0.767	0.777	0.765	0.809	0.757	0.780
0.029 ma.	0.741	0.838	0.761	0.780	0.759	0.835	0.755	0.783
0.035 ma.	0.734	0.843	0.759	0.795	0.757	0.842	0.754	0.784
0.046 ma.	0.731	0.852	0.755	0.817	0.754	0.849	0.754	0.786
0.075 ma.	0.724	0.865	0.749	0.830	0.748	0.863	0.751	0.791
0.100 ma.	0.717	0.879	0.741	0.833	0.743	0.874	0.748	0.796
0.150 ma.	0.716	0.894	0.732	0.837	0.737	0.890	0.745	0.811
0.300 ma.	0.704	0.876	0.721	0.845	0.722	0.892	0.737	0.825

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FIGURE 7 (Cont.)

ANODIC POLARIZATION				
Anodic Polarization Current Density			4.33 ma./sq.cm.	
Inhibitor	0.2% AmCr + 0.1% Ant.R155		0.2% Hg in Zn + 0.1% Ant.R155	
	After 24 hrs at 70° F	After 24 hrs at 130° F	After 24 hrs at 70° F	After 24 hrs at 130° F
O.C.V. before polarization	0.774 v.	0.744 v.	0.797 v.	0.798 v.
Time polarized	Anode Voltage			
1 second	0.578 v.	0.453 v.	0.648 v.	0.718 v.
15 "	0.631 v.	0.468 v.	0.674 v.	0.711 v.
30 "	0.633 v.	0.468 v.	0.683 v.	0.713 v.
60 "	0.638 v.	0.458 v.	0.690 v.	0.714 v.
90 "	0.645 v.	0.461 v.	0.693 v.	0.714 v.
120 "	0.650 v.	0.465 v.	0.696 v.	0.715 v.
180 "	0.658 v.	0.467 v.	0.701 v.	0.717 v.
240 "	0.662 v.	0.468 v.	0.703 v.	0.717 v.

CATHODIC AND ANODIC POLARIZATION								
Inhibitor	0.2% AmCr + 0.1% Ant. R155				0.2% Hg in Zn + 0.1% Ant.R155			
	Tested @ 70°F		Tested @ 130°F		Tested @ 70°F		Tested @ 130°F	
	OCV - 0.780 v.		OCV - 0.775 v.		OCV - 0.786 v.		OCV - 0.779 v.	
Polarization Current	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage
0.01 ma.	0.766	0.813	0.770	0.814	0.743	0.874	0.773	0.843
0.029 ma.	0.753	0.845	0.756	0.840	0.734	0.897	0.764	0.859
0.035 ma.	0.750	0.851	0.750	0.852	0.732	0.898	0.762	0.859
0.046 ma.	0.747	0.861	0.746	0.871	0.732	0.900	0.756	0.865
0.075 ma.	0.739	0.881	0.730	0.894	0.727	0.887	0.748	0.883
0.100 ma.	0.732	0.895	0.732	0.898	0.729	0.891	0.739	0.891
0.150 ma.	0.718	0.908	0.708	0.897	0.725	0.892	0.729	0.899
0.300 ma.	0.696	0.948	0.700	0.915	0.721	0.902	0.707	0.892

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FIGURE 7 (Cont.)

ANODIC POLARIZATION				
Anodic Polarization Current Density			4.33 ma./sq.cm.	
Inhibitor	0.2% AmCr + 0.3% Ant. A403		0.2% Hg in + 0.3% Ant. A403	
	After 24 hrs at 70° F	After 24 hrs at 130° F	After 24 hrs. at 70° F	After 24 hrs at 130° F
O.C.V. before polarization	0.790 v.	0.769 v.	0.807 v.	0.801 v.
Time polarized	Anode Voltage			
1 second	0.613 v.	0.683 v.	0.753 v.	0.796 v.
15 "	0.629 v.	0.698 v.	0.753 v.	0.787 v.
30 "	0.626 v.	0.705 v.	0.752 v.	0.786 v.
60 "	0.616 v.	0.713 v.	0.754 v.	0.786 v.
90 "	0.605 v.	0.717 v.	0.756 v.	0.787 v.
120 "	0.596 v.	0.719 v.	0.757 v.	0.786 v.
180 "	0.585 v.	0.721 v.	0.758 v.	0.787 v.
240 "	0.578 v.	0.723 v.	0.760 v.	0.787 v.

CATHODIC AND ANODIC POLARIZATION								
Inhibitor	0.2% AmCr + 0.3% Antarox A403				0.2% Hg in Zn + 0.3% Ant. A403			
	Tested @ 70°F		Tested @ 130°F		Tested @ 70°F		Tested @ 130°F	
	OCV - 0.796 v.		OCV - 0.766 v.		OCV - 0.808 v.		OCV - 0.802 v.	
Polarization Current	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage
0.01 ma.	0.787	0.798	0.748	0.722	0.807	0.808	0.802	0.802
0.029 ma.	0.774	0.814	0.747	0.778	0.807	0.809	0.802	0.802
0.035 ma.	0.771	0.821	0.747	0.783	0.807	0.810	0.802	0.803
0.046 ma.	0.766	0.825	0.746	0.793	0.807	0.810	0.802	0.803
0.075 ma.	0.756	0.839	0.745	0.805	0.806	0.811	0.802	0.803
0.100 ma.	0.752	0.848	0.742	0.819	0.806	0.813	0.802	0.804
0.150 ma.	0.743	0.873	0.740	0.835	0.805	0.816	0.802	0.804
0.300 ma.	0.735	0.887	0.739	0.865	0.803	0.825	0.802	0.806

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FIGURE 7 (Cont.)

ANODIC POLARIZATION				
Anodic Polarization Current Density			4.33 ma./sq.cm.	
Inhibitor	0.2% AmCr + 0.3% Neut.		0.2% Hg in Zn + 0.3% Neut.	
	After 24 hrs at 70° F	After 24 hr at 130° F	After 24 hrs. at 70° F	After 24 hrs. at 130° F
O.C.V. before polarization	0.768 v.	0.766 v.	0.806 v.	0.798 v.
Time polarized	Anodic Voltage			
1 second	0.663 v.	0.658 v.	0.718 v.	0.761 v.
15 "	0.703 v.	0.656 v.	0.7 20 v.	0.744 v.
30 "	0.707 v.	0.655 v.	0.723 v.	0.743 v.
60 "	0.712 v.	0.653 v.	0.728 v.	0.742 v.
90 "	0.714 v.	0.656 v.	0.732 v.	0.743 v.
120 "	0.715 v.	0.656 v.	0.735 v.	0.743 v.
180 "	0.715 v.	0.657 v.	0.739 v.	0.743 v.
240 "	0.716 v.	0.658 v.	0.741 v.	0.743 v.

Cathodic and Anodic Polarization								
Inhibitor	0.2% AmCr + 0.3% Neutronyx				0.2% Hg in Zn + 0.3% Neutronyx			
	Tested @ 70°F		Tested @ 130°F		Tested @ 70°F		Tested @ 130°F	
	OCV - 0.778 v.		OCV - 0.756 v.		OCV - 0.807 v.		OCV - 0.802 v.	
Polarization Current	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage	Anode Voltage	Cathode Voltage
0.01 ma.	0.776	0.798	0.742	0.787	0.807	0.808	0.802	0.802
0.029 ma.	0.774	0.820	0.736	0.823	0.805	0.811	0.802	0.803
0.035 ma.	0.771	0.830	0.735	0.831	0.804	0.812	0.802	0.803
0.046 ma.	0.766	0.837	0.733	0.839	0.803	0.813	0.802	0.803
0.075 ma.	0.758	0.852	0.727	0.852	0.801	0.817	0.802	0.804
0.100 ma.	0.751	0.862	0.730	0.865	0.799	0.820	0.801	0.804
0.150 ma.	0.742	0.883	0.724	0.882	0.796	0.827	0.801	0.804
0.300 ma.	0.721	0.903	0.716	0.887	0.788	0.850	0.799	0.806

FIGURE 7A

ANODIC POLARIZATION OF ZINC

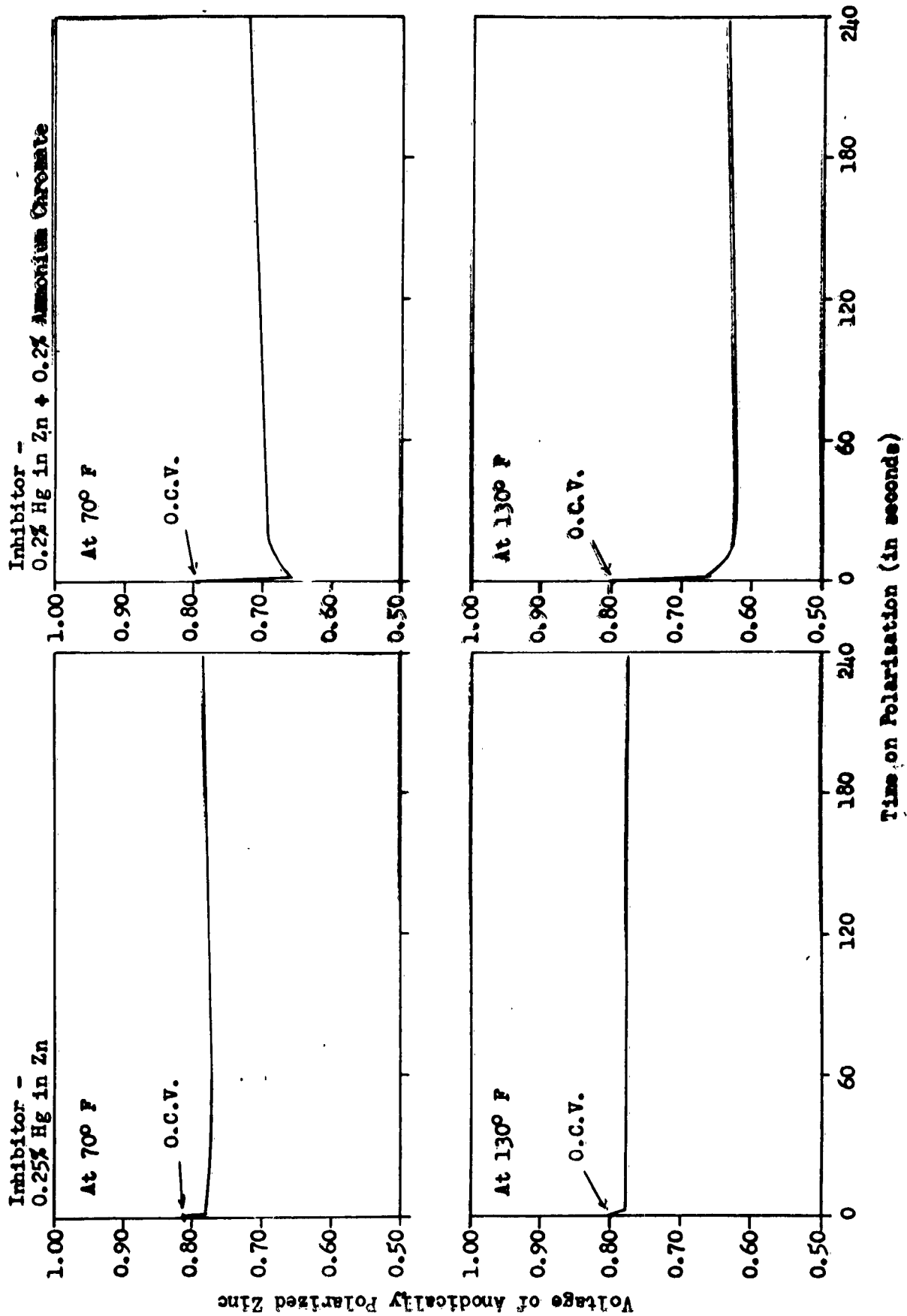


FIGURE 7A (Cont.)

ANODIC POLARIZATION OF ZINC

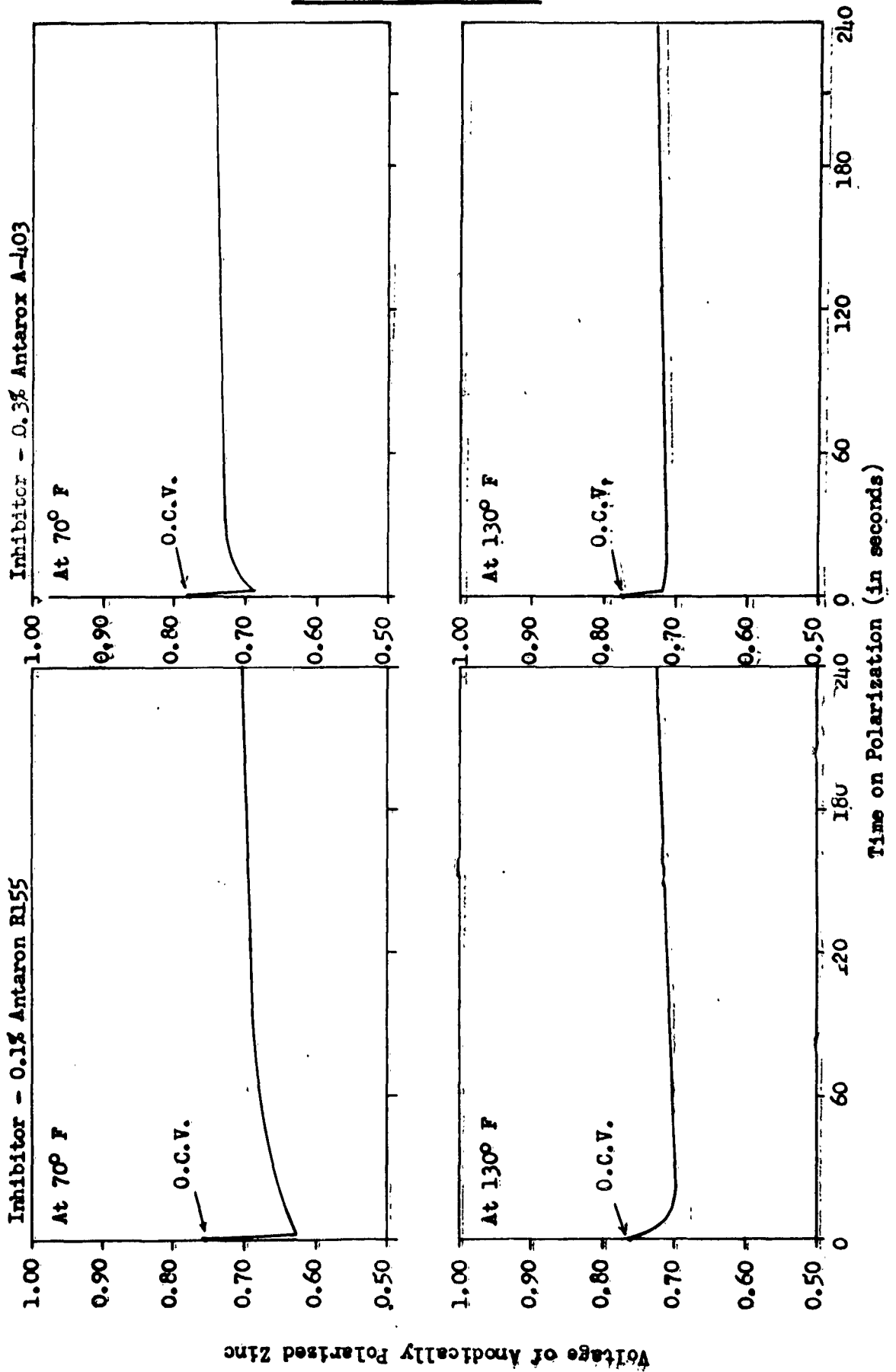


FIGURE 7A (Cont.)

ANODIC POLARIZATION OF ZINC

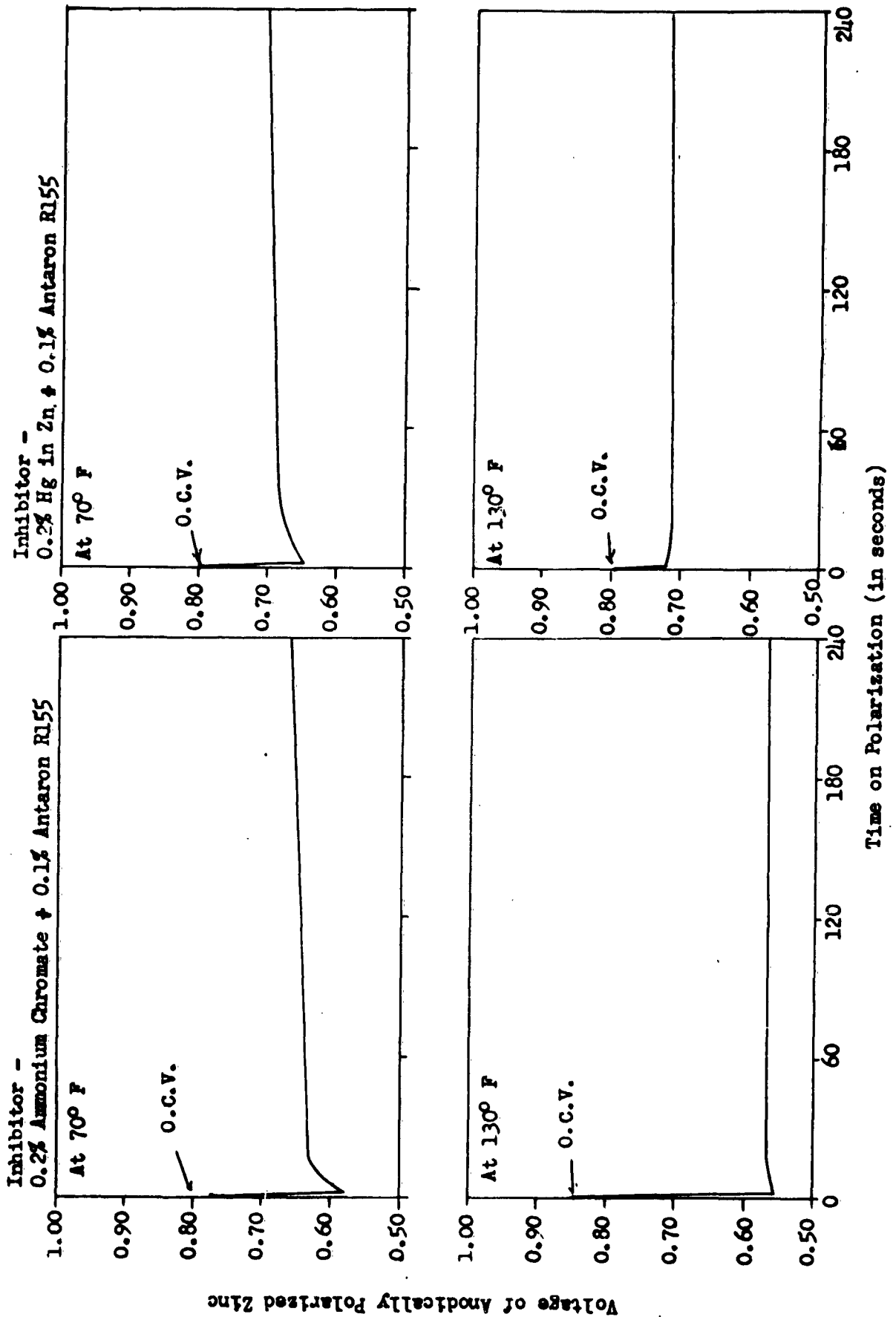


FIGURE 7A (Cont.)

ANODIC POLARIZATION OF ZINC

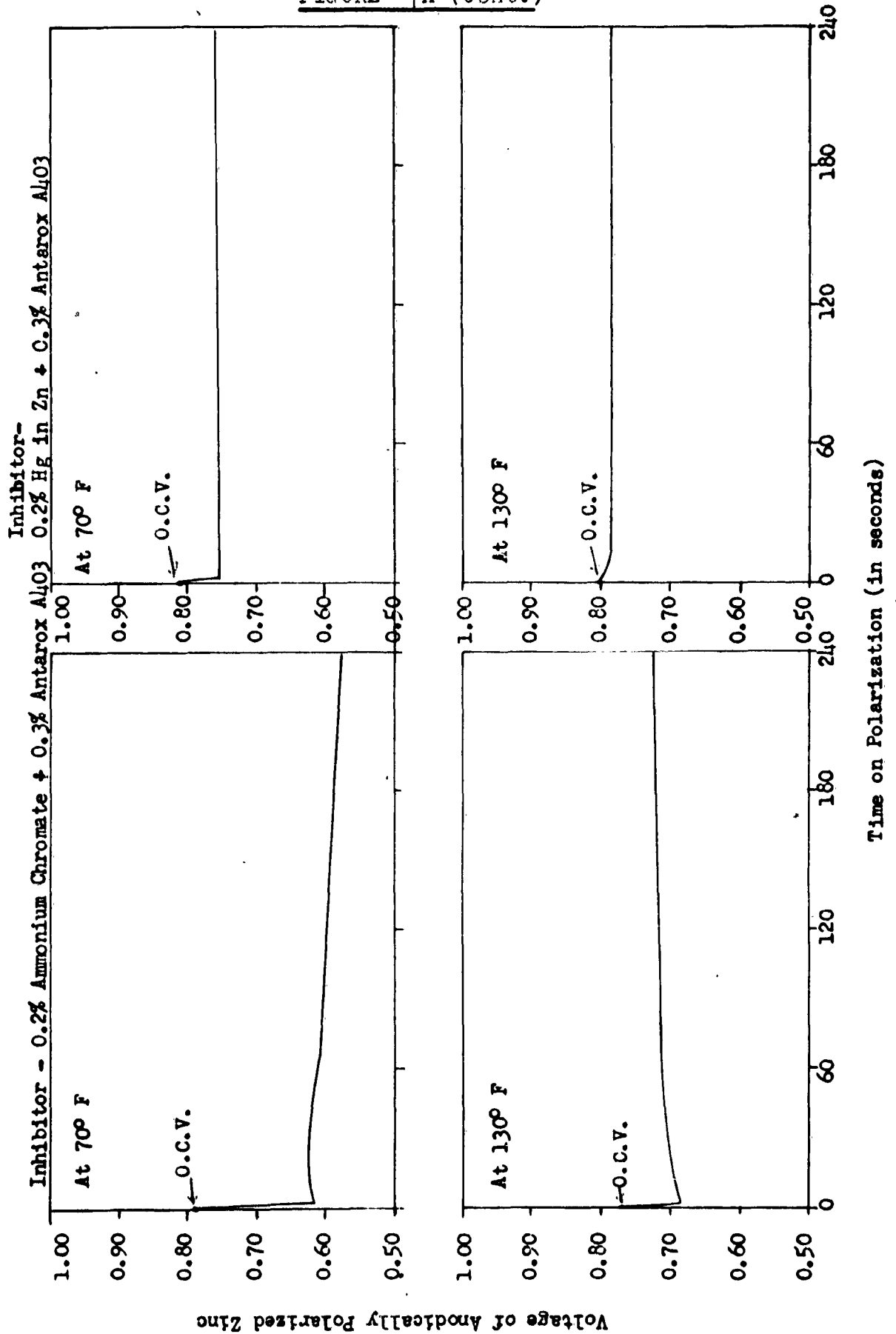
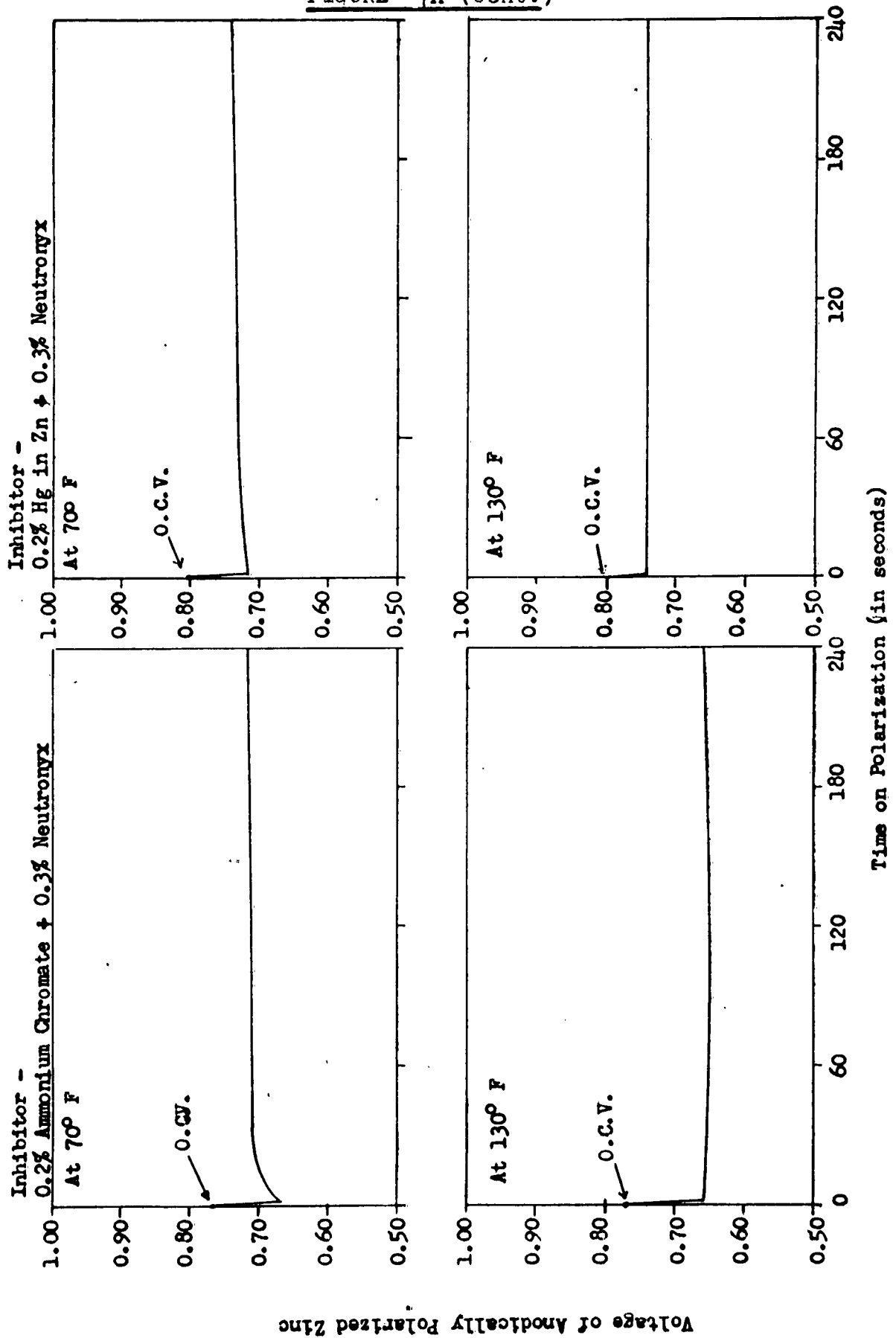


FIGURE 7A (Cont.)

ANODIC POLARIZATION OF ZINC



Voltage of Anodically Polarized Zinc

FIGURE 7B

Anodic and Cathodic Polarization of Zinc

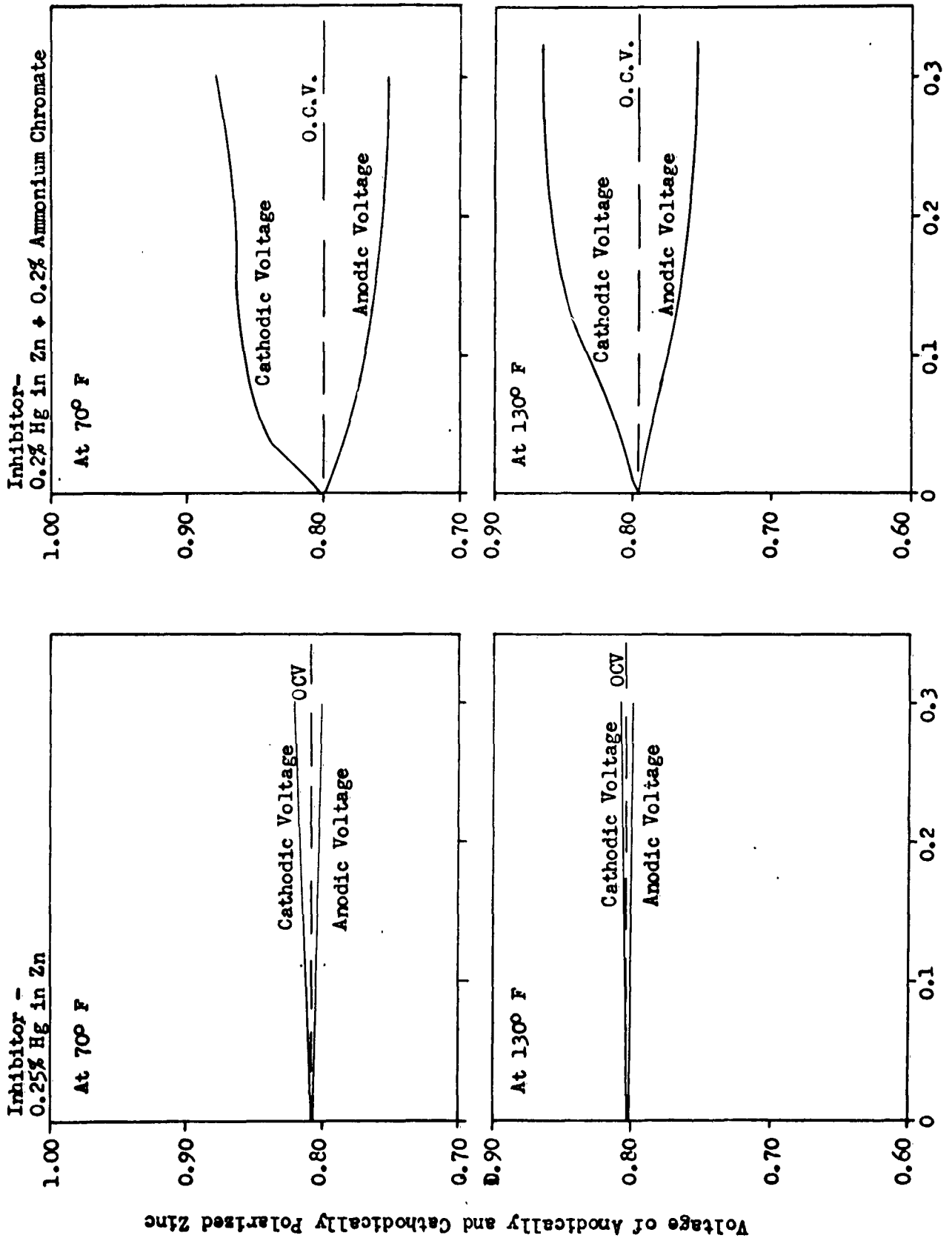


FIGURE 7B (Cont.)

ANODIC AND CATHODIC POLARIZATION OF ZINC

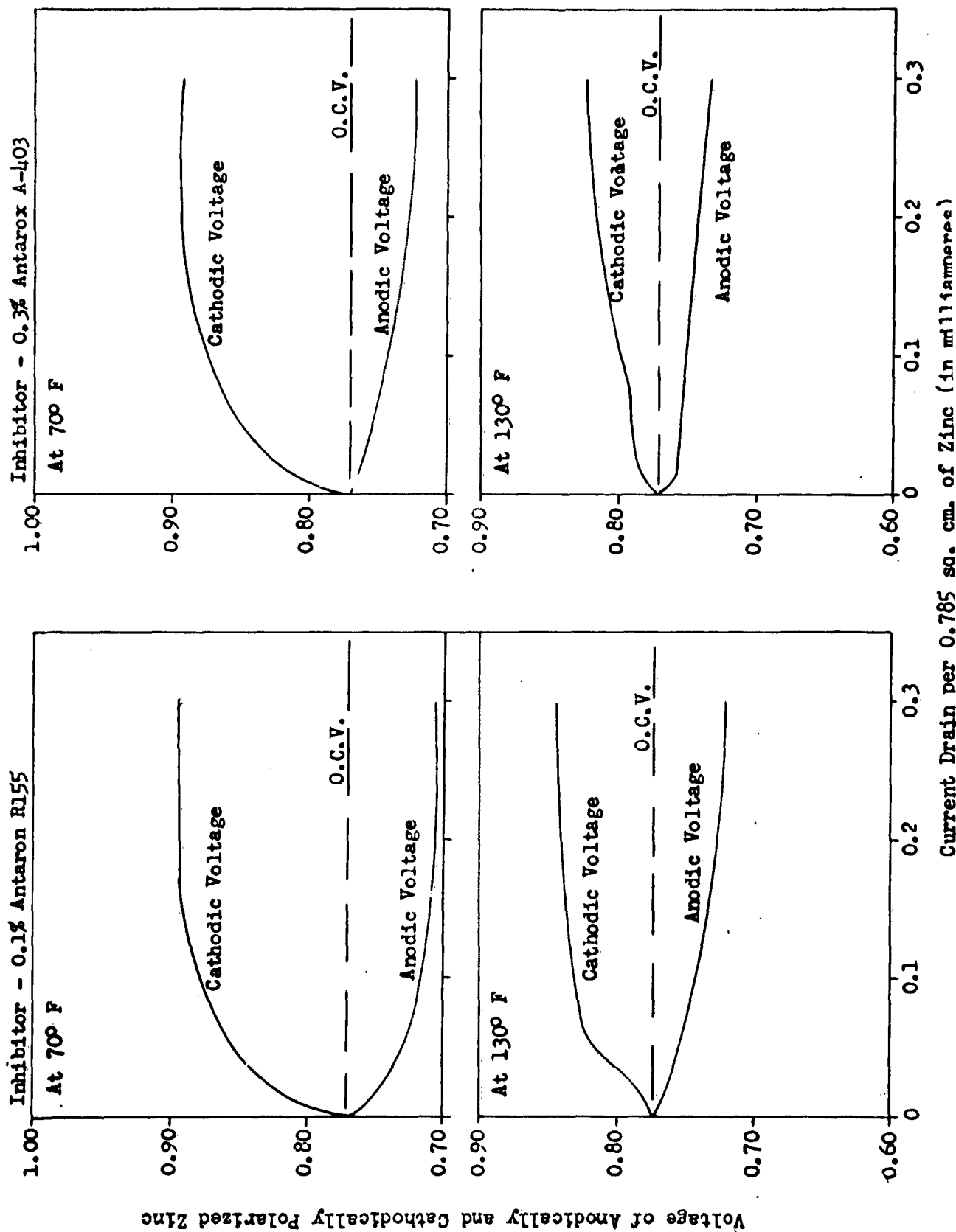
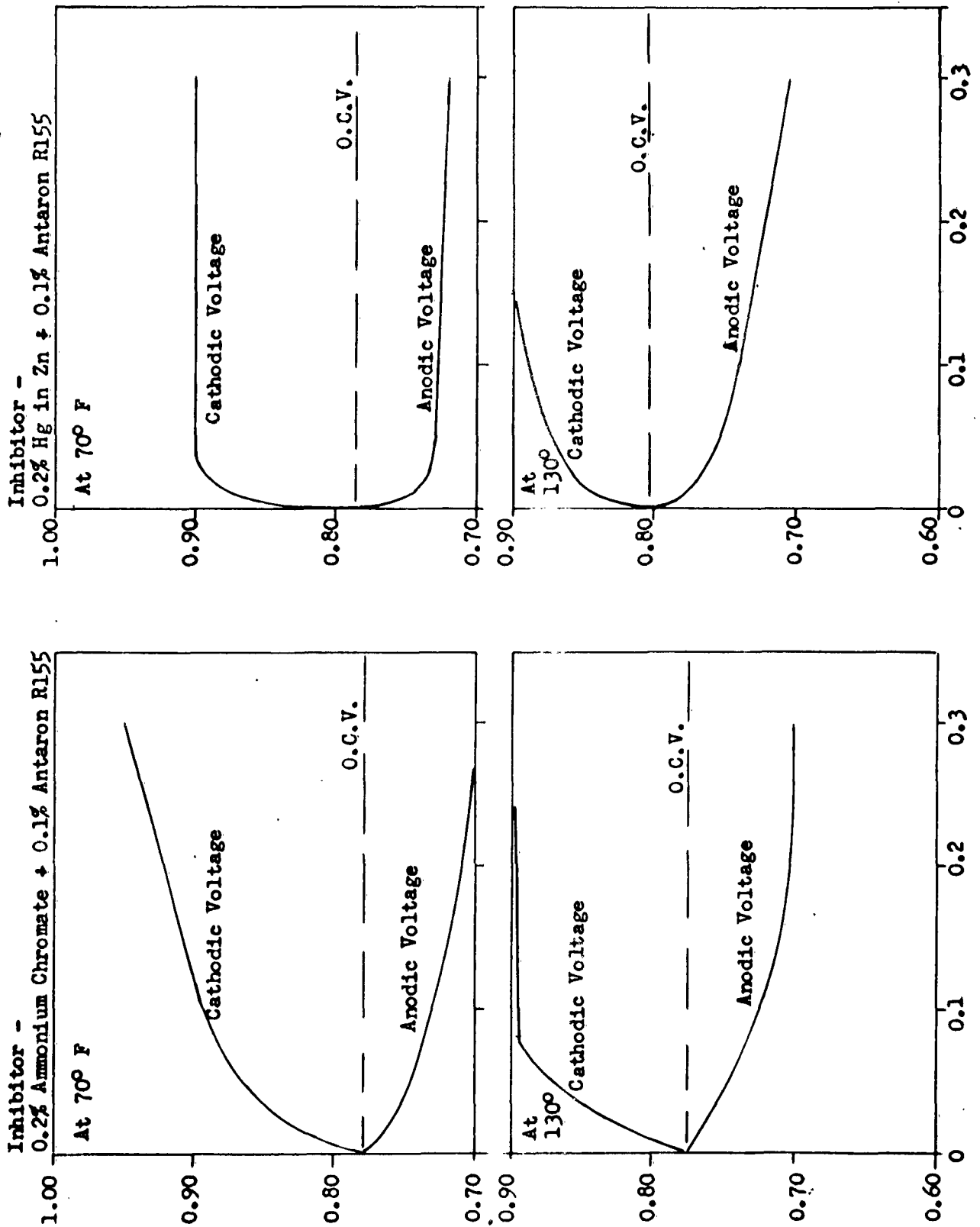


FIGURE 7B (Cont.)

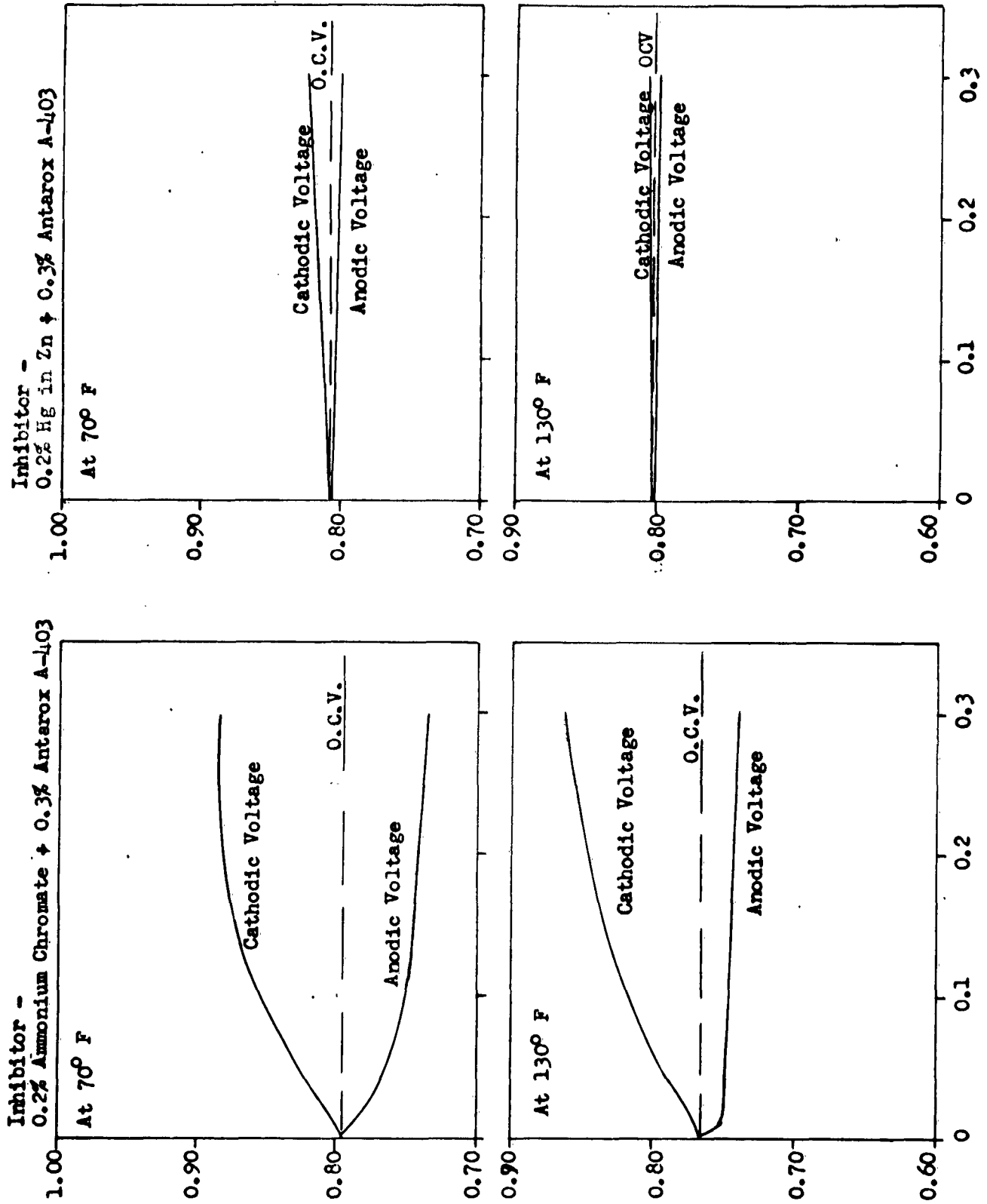
ANODIC AND CATHODIC POLARIZATION OF ZINC



Voltage of Anodically and Cathodically Polarized Zinc

FIGURE 7B (Cont.)

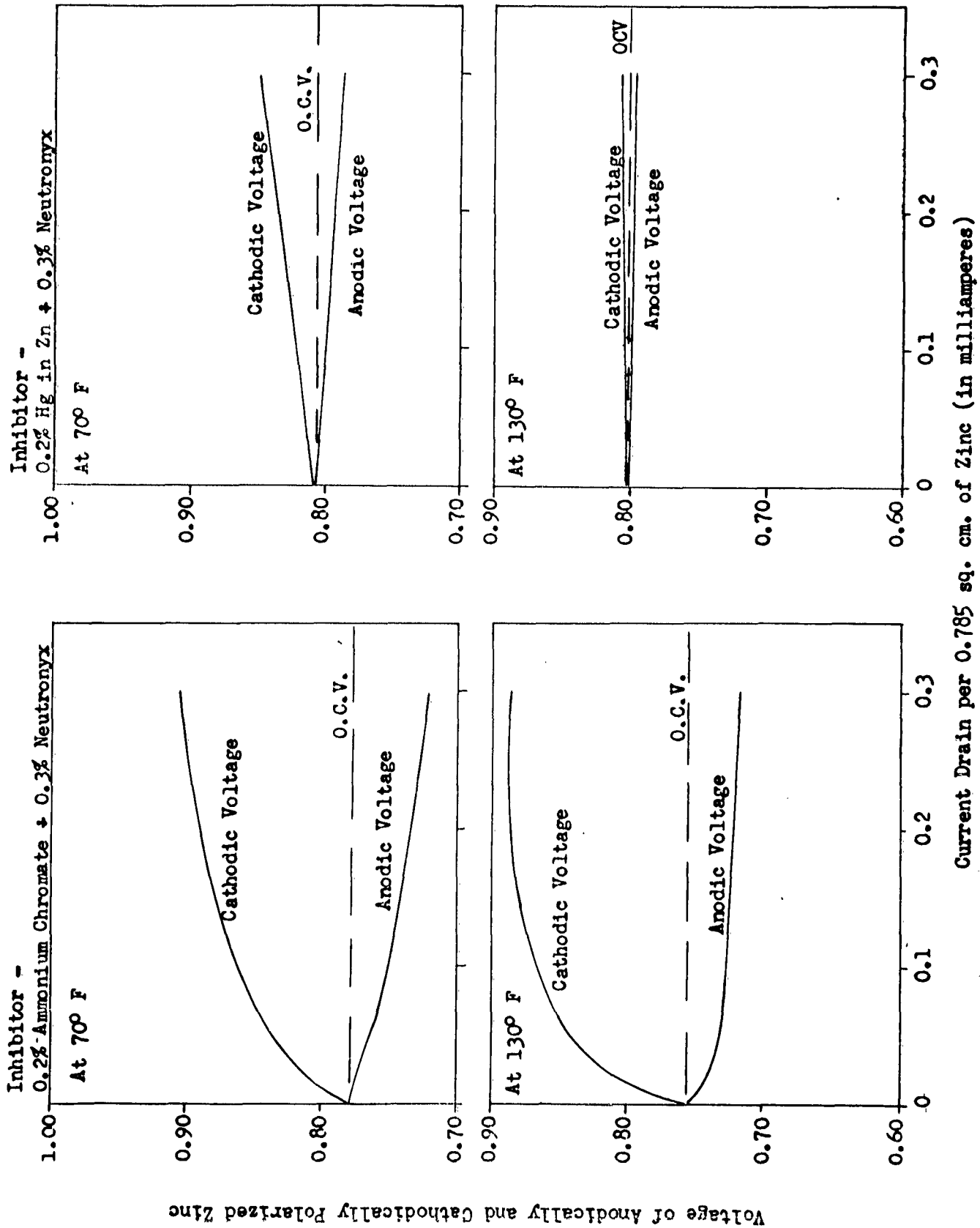
ANODIC AND CATHODIC POLARIZATION OF ZINC



Voltage of Anodically and Cathodically Polarized Zinc

FIGURE 7B (Cont.)

ANODIC AND CATHODIC POLARIZATION OF ZINC



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FIGURE 8

Visual Corrosion Studies (Zinc partially immersed)

Storage Conditions.		Strip of zinc stored in electrolyte containing inhibitor. Inhibitor percentage by weight of electrolyte. Sample stored at 113°F for one year.			
Sample No.	Inhibitor	Percent of Inhibitor	Weight of zinc		Percent of weight lost
			Initially	After 12 mos at 113°F	
1	Antarox A-200	0.05%	1.20 gm.	0.93 gm.	22.5%
2		0.20	1.21	0.95	21.5
3		0.50	1.33	1.05	21.1
4	Antarox D-100	0.05	1.27	0.98	22.8
5		0.20	1.45	1.06	26.7
6		0.50	1.05	0.81	22.8
7	Antarox A-403	0.05	1.16	0.87	25.0
8		0.20	1.24	0.91	26.6
9		0.50	1.20	0.91	24.1
10	Antarox A-400	0.05	1.35	1.06	21.5
11		0.20	1.10	0.82	25.4
12		0.50	1.20	0.99	17.5
13	Quaternar C"	0.05	1.29	1.00	22.5
14		0.20	1.01	0.77	24.7
15		0.50	1.15	0.96	16.5
16	Amine "C"	0.05	1.28	1.07	16.4
17		0.20	1.11	0.93	16.2
18		0.50	1.07	----	----
19	Antaron R-155	0.05	1.30	1.07	17.7
20		0.20	1.16	0.99	14.6
21		0.50	1.19	1.00	16.0
22	Detergent D-60FG	0.05	1.33	1.06	20.3
23		0.20	1.16	0.90	22.4
24		0.50	1.03	0.92	10.7
25	Sequestrene NA-2	0.05	1.09	0.88	19.3
26		0.20	1.08	0.67	37.0
27		0.50	1.13	0.79	30.1

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FIGURE 8 (cont.)

Sample No.	Inhibitor	Percent of inhibitor	Weight of zinc		Percent of weight lost
			Initially	After 12 mos.- 113°F	
28	Sequestrene NA-4	0.05	1.19 gm.	0.98 gm.	17.6%
29		0.20	1.30	1.11	14.6
30		0.50	1.10	----	----
31	Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>	0.05	1.21	1.00	17.4
32		0.20	1.16	1.05	9.5
33		0.50	1.43	1.34	6.3
34		1.00	1.32	1.27	3.8
35		2.00	1.08	1.05	2.8
36	Denatured Gluten	0.50	1.24	0.98	21.0
37		1.00	1.37	----	----
38		2.00	1.35	----	----
39	Special Wheat Protein R2E-570	0.50	1.18	0.90	23.8
40		1.00	1.32	1.21	8.4
41		2.00	1.05	----	----
42	Protein #3323	0.50	1.19	----	----
43		1.00	1.33	----	----
44		2.00	1.30	----	----
45	Devitalized Wheat Gluten	0.50	1.14	----	----
46		1.00	1.15	0.920	20.0
47		2.00	1.19	----	----
48	Triticote #87	0.50	1.28	----	----
49		1.00	1.21	-----	----
50		2.00	1.11	0.81	27.0
51	Special Wheat Protein R2E-1301	0.50	1.24	1.00	19.3
52		1.00	1.05	----	----
53		2.00	1.41	1.09	22.7
54	Mercury in zinc	0.05	1.22	0.99	18.8
55	Mercury in zinc	0.10	1.27	1.00	21.6
56	Mercury in zinc	0.20	1.16	0.89	23.2
57	Mercury in zinc	0.30	1.14	0.76	33.3
58	Mercury in zinc	0.40	1.26	0.67	47.0

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FIGURE 9

Visual Corrosion Studies (Zinc totally immersed)

Storage Conditions		Strip of zinc stored in electrolyte containing inhibitor. Inhibitor percentage by weight of electrolyte. Sample stored at 113°F for one year.			
Sample No.	Inhibitor	percent of Inhibitor	Weight of zinc		Percent of weight lost
			Initially	after 12 mos.- 113°F	
1	Antarox A-200	0.05%	0.84 gm.	0.71 gm.	15.5%
2		0.20	0.60	0.46	25.3
3		0.50	0.47	0.39	17.0
4	Antarox D-100	0.05	0.80	0.66	17.5
5		0.20	0.71	0.54	24.0
6		0.50	0.80	0.68	15.0
7	Antarox A-403	0.05	0.75	0.61	18.7
8		0.20	0.59	0.48	18.7
9		0.50	0.63	0.57	9.5
10	Antarox A-400	0.05	0.80	0.68	15.0
11		0.20	0.65	0.51	21.6
12		0.50	0.64	0.52	18.8
13	Quaternary "C"	0.05	0.89	0.71	20.0
14		0.20	0.71	0.58	18.3
15		0.50	0.87	0.72	17.2
16	Amine "C"	0.05	0.78	0.58	25.6
17		0.20	0.78	0.67	14.1
18		0.50	0.77	0.69	10.4
19	Antaron R-155	0.05	0.82	0.74	9.8
20		0.20	0.70	0.61	12.8
21		0.50	0.71	0.63	11.3
22	Detergent D-60FG	0.05	0.78	0.67	14.1
23		0.20	0.74	0.68	8.1
24		0.50	0.71	0.53	25.4
25	Sequestrene NA-2	0.05	0.80	0.62	22.5
26		0.20	0.72	0.60	16.7
27		0.50	0.80	0.68	15.0

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FIGURE 9 (cont.)

Sample No/	Inhibitor	Percent of Inhibitor	weight of zinc		Percent of weight lost
			Initially	After 12 mos. -113°F	
28	Sequestrene NA-4	0.05%	0.86 gm.	0.61 gm.	29.0%
29		0.20	0.81	0.61	24.8
30		0.50	0.90	0.62	31.1
31	Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>	0.05	0.87	0.81	6.9
32		0.20	0.79	0.74	6.3
33		0.50	0.73	0.69	5.5
34		1.00	0.71	0.68	4.2
35		2.00	0.65	0.62	4.6
36		0.50	0.75	0.66	12.0
37	Denatured Gluten	1.00	0.77	0.65	15.6
38		2.00	0.81	0.69	14.8
39	Special Wheat Protein R2E-570	0.50	0.74	0.70	5.4
40		1.00	0.70	0.65	7.2
41		2.00	0.70	0.60	14.3
42	Protein #3323	0.50	0.65	0.57	18.5
43		1.00	0.73	0.64	12.3
44		2.00	0.64	0.52	18.8
45	Devitalized Wheat Gluten	0.50	0.76	0.70	7.9
46		1.00	0.82	0.63	23.2
47		2.00	0.72	0.59	18.1
48	Triticote #87	0.50	0.68	0.59	13.2
49		1.00	0.77	0.64	16.9
50		2.00	0.79	0.62	21.5
51	Special Wheat Protein R2E-1301	0.50	0.71	0.63	11.3
52		1.00	0.75	0.63	16.0
53		2.00	0.76	0.69	9.2
54	Mercury in zinc	0.05	0.65	0.52	20.0
55	Mercury in zinc	0.10	0.81	0.60	18.5
56	Mercury in zinc	0.20	0.81	0.57	29.6
57	Mercury in zinc	0.30	0.66	0.44	33.4
58	Mercury in zinc	0.40	0.54	0.13	76.0

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## **PART VI**

# **CONSTRUCTION AND CAPACITY RESULTS OF STORED CELLS**

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Part VI - Capacity Results of Cells Stored at the Temperatures Specified by the Contract

Exploratory experiments have been done in an effort to determine what structural changes must be made in conventional cells in order that they may meet the specifications required by this contract, namely, storage twelve months at 113°F, 95% R.H., three months at 130°F, 50% R.H. and two weeks at 160°F, 50% R.H. After this storage period, it is desired that the cells have capacities at least one half of the initial capacities of corresponding cells.

Some satisfactory data have been obtained but the problem of subseal leakage was a serious one. The subseal used was a high melting form of Amprol wax (Atlantic Refining Company). This wax does not normally flow at 160°F but under the pressure generated in cells stored at 160°F it is forced out around the top seal.

In order to overcome this problem several different types of waxes were tested, but none was found which could be handled satisfactorily and still not result in subseal leakage. Another method was found however that decreased the subseal and paste leakage considerably and, in many cases, stopped it completely. This method involved the use of a polyethylene gasket incorporated into the top seal design. This gasket was crimped between the zinc can and the plastic top seal making a tight seal at this point and at the same time it gave a tight seal between the top seal and the carbon rod. This gasket was used with and without a wax subseal and the results were compared to those using a conventional amprol wax subseal. These results are shown in Figure #1. A heat resistant polystyrene cap has been used as the final top seal and has proven to be very satisfactory. This cap is held in place by crimping the top of the zinc can.

Several lots of fabricated cells contained 100% African ore mixes in which conventional inhibitors were tested. Both conventional starch formulations (corn starch, potato starch and flour) and modified starch formulations were used. Other lots were made in which 100% Cryptomelane and 30% Cryptomelane - 70% African ore mixes were employed. Several types (morphological) of Cryptomelane were tried in the latter tests. A conventional separator of corn starch, potato starch, flour and electrolyte and a mercury inhibitor were used in those cells containing Cryptomelane ores.

The best results were obtained with cells using sodium dichromate as the inhibitor. In the cases where the dichromate was used as the inhibitor a reservoir of chromate ions was added to the mix in the form of chromic oxide or barium chromate. Since the ore has a tendency to absorb chromate ions, this reservoir was added to satisfy the absorption rather than taking the ions from the inhibitor in the paste.

In many cases it has been noticed that the use of chromate as an inhibitor seriously decreases delayed room temperature capacity due to the passivation of the zinc by the chrome film. The reason that excellent elevated temperature

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capacity is obtained may be that the passivating tendency of the chrome film is decreased. This has been shown to be true from polarization studies.

The use of chromic oxide or barium chromate as the ion reservoir does, however, make considerable difference. Cells using chromic oxide gave very poor results while those using barium chromate gave very good results. This has been also found to be true with cells stored at 160°F.

The capacity results obtained from cells at 130°F. show, as did the results obtained from cells stored at 160°F. and 113°F., that African ore appears to give more satisfactory and consistent results than do blends of African and an activated ore probably due to the fact that the African ore undergoes less change in crystal structure during the storage period than do the activated ores.

The evaluation of Anodite and Cryptolite as the depolarizer for high temperature shows that best results are obtained when they are blended with African ore (30% Cryptolite or Anodite - 70% African ore).

Capacity results of fabricated cells after storage are condensed and tabulated under storage temperature. Figures 2, 3 and 4 are for those cells which were stored twelve months at 113°F, 95% R.H., while Figures 5 and 6 are for cells stored three months at 130°F, 50% R.H., and Figures 7 and 8 are for cells stored two weeks at 160°F, 50% R.H.

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Conclusions

1. Capacity results of cells stored at temperatures specified by the contract shows that:

- a. Cells can be made which operate satisfactorily after storage for one year at 113°F. 95% R.H.
- b. Cells can be made which operate satisfactorily after storage for ~~one year~~ *3 months* at 130°F. 50% R.H.
- c. Cells can be made which operate satisfactorily after storage for two weeks at 160°F. 50% R.H.

2. African ore appears to be the most satisfactory manganese dioxide for elevated temperature storage especially when cells are stored for an extended period.

3. Increased capacity and decreased leakage can be obtained from cells stored at 160°F. by the use of a polyethylene gasket, substituted for the wax sub-seal, and incorporating it as part of the heat resistant polystyrene top seal.

4. Using Cryptomelane in blends with African ore gave excellent results after storage at 113°F. 95% R.H. for a period of one year.

5. Best capacity results from cells stored at either 130°F. or 160°F. were obtained from those using sodium dichromate, a combination of sodium dichromate and Antaron R-155 or a combination of mercury and Antaron R-155 as the inhibitor.

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TABLES AND RESULTS

PART VI

CONSTRUCTION AND CAPACITY RESULTS OF CELLS  
STORED AT THE SPECIFIED TEMPERATURES OF  
THE CONTRACT.

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FIGURE (1)

Comparative Capacity Results Of Cells Stored At 160°F

Storage conditions before initially testing		2 weeks at 70°F, 50% R.H.		
Storage conditions for cells stored at 160°F (tested at 70°F)		2 weeks at 70°F, 50% R.H. 2 weeks at 160°F, 50% R.H.		
Test	Testing Time	Type of Subseal		
		Amprol wax	Amprol wax with polyethylene gasket	Polyethylene gasket - no wax subseal
BA-30 (days)	Initially	13.7	13.7	13.7
	After 2 wks. at 160°F	5.7	11.5	11.0
BA-8 (hrs.)	Initially	244.0	244.0	244.0
	After 2 wks. at 160°F	143.0	180.4	168.8
BA-408 (hrs.)	Initially	22.6	22.6	22.6
	After 2 wks. at 160°F	11.6	16.8	17.8

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CONSTRUCTION AND CAPACITY RESULTS OF CELLS

STORED AT

113° F.

FOR 1 YEAR AT 95% R.H.

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FIGURE 2

LeClanché Type "D" Cells For Storage At 113° F. (Construction)

Storage Time Before Initial Testing At 70° F.		2 weeks at 70°F - 50% R.H.		
Storage Time For Cells Stored At 113°F (Tested at 70°F)		1 month at 70°F - 50% R.H. 1 year at 113°F - 95% R.H.		
Lot No.	Mix Formulation	Separator	Subseal	Seal
B2148	100% African Ore 7/1 - ore/black	Starch - flour paste 0.3% HgCl <sub>2</sub> as inhibitor	Amprol wax	Bakelite cap
B2149	100% African ore 7/1 - ore/black	Starch - flour paste 0.3% HgCl <sub>2</sub> as inhibitor	Amprol wax	Bakelite cap
B2150	100% African ore 7/1 - ore/black 0.5% CrO <sub>3</sub>	Starch - flour paste 0.3% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> as inhibitor	Amprol wax	Bakelite cap
B2151	100% African ore 7/1 - ore/black 1.0% BaCrO <sub>4</sub>	Starch - flour paste 0.3% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> as inhibitor	amprol wax	Bakelite cap
B2152	100% African ore 7/1 - ore/black 1.0% BaCrO <sub>4</sub>	Specially treated starch - 0.3% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> as inhibitor	amprol wax	Bakelite cap
B2473	100% African ore 7/1 - ore/black 0.5% CrO <sub>3</sub>	Specially treated starch - 0.3% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> as inhibitor	amprol wax	Bakelite cap
B2474	100% African ore 7/1 ore/black 0.5% CrO <sub>3</sub>	Starch - flour paste Cans were Cronak treated	amprol wax	Bakelite cap
B2475	100% African ore 7/1 - ore/black 1.0% BaCrO <sub>4</sub>	Special starch paste Cans were Cronak treated	amprol wax	Bakelite cap

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FIGURE 2 (cont.)

Lot No.	Mix Formulation	Separator	Subseal	Seal
B2476	100% African ore 7/1 - ore/black 1.0% BaCrO <sub>4</sub>	Starch - flour paste Cans were Cronak treated	amprol wax	Bakelite cap
B2477	100% African ore 7/1 - ore/black	Starch - flour paste 0.5% Antarox A-403 as inhibitor	amprol wax	Bakelite cap
B2478	100% African ore 7/1 - ore/black	Starch - flour paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	Bakelite cap
B2479	100% African ore 7/1 - ore/black 0.5% CrO <sub>3</sub>	Starch - flour paste 0.3% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> as inhibitor	amprol wax	Bakelite cap
B2480	100% African ore 7/1 - ore/black 1.0% BaCrO <sub>4</sub>	Starch - flour paste 0.3% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> as inhibitor	amprol wax	Bakelite cap
B2611	20% Light Hydrate 80% African ore 7/1 - ore/black	Special starch paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	Bakelite cap

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FIGURE 2A

LeClanché Type "D" Cells Stored at 113° F (Capacity)

Lot No.	Test Results						
	Cell No.	BA-30 (days)		BA-8 (hours)		BA-408/U (hours)	
		Initial	1 year at 113° F	Initial	1 year at 113° F	Initial	1 year at 113° F
B2148	1	13.7	4.6	193.0	96.0	19.0	12.0
	2	13.5	5.0	212.0	104.0	19.0	10.7
	3		5.0	200.0	88.0	19.0	12.6
	Ave.	13.6	4.9	202.0	96.0	19.0	11.8
B2149	1	12.8	8.4	205.0	112.0	17.0	11.3
	2	13.2	8.2	206.0	126.4	17.0	11.1
	3	13.4	10.2	206.0	129.6	17.0	13.5
	Ave.	13.1	8.9	206.0	122.6	17.0	11.8
B2150	1	14.4	Cells	207.0	Cells	18.0	Cells
	2	14.6	no	210.0	no	17.0	no
	3	14.4	good	206.0	good	18.0	good
	Ave.	14.5	----	208.0	----	17.7	----
B2151	1	14.2	8.0	196.0	150.4	17.0	13.5
	2	13.6	5.8	219.0	130.7	17.0	14.1
	3	13.2		208.0	147.2	16.0	14.7
	Ave.	13.7	6.9	208.0	143.0	16.6	14.1
B2152	1	13.6	1.5	195.0	Cells	16.0	14.0
	2	13.6		195.0	no	17.0	
	3	14.0		192.0	good	17.0	
	Ave.	13.7	1.5	194.0	----	16.6	14.0
B2473	1	14.4	10.0	194.0	133.1	18.0	14.8
	2	14.0	10.2	195.0	146.3	18.0	16.0
	3	12.8	10.8	194.0	137.4	17.0	16.6
	Ave.	13.7	10.4	194.0	138.9	17.6	15.8
B2474	1	13.6	Cells	195.0	Cells	18.0	Cells
	2	14.0	no	208.0	no	17.0	no
	3	13.0	good	200.0	good	16.0	good
	Ave.	13.5	----	201.0	----	17.0	----
B2475	1	12.2	8.4	193.0	138.2	18.0	13.6
	2	12.2	7.8	183.0	139.4	17.0	14.1
	3	12.4	7.8	194.0	140.8	17.0	15.1
	Ave.	12.3	8.0	190.0	139.5	17.3	14.3

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FIGURE 2A (cont.)

Lot No.	Test Results						
	Cell No.	BA-30 (days)		BA-8 (hours)		BA-408/U (hours)	
		Initial	After 1 yr. -1130	Initial	1 year at 1130F	Initial	1 year at 1130F
B2476	1	13.8	6.2	184	126.4	17.0	13.6
	2	13.0	6.0	200	125.1	17.0	15.2
	3	13.0	7.2	200	130.0	17.0	15.6
	Ave.	13.3	6.5	195	127.2	17.0	14.8
B2477	1	13.0	4.6	208	119.4	15.0	11.1
	2	13.0	7.4	203	128.0	15.0	13.3
	3	13.8	7.6	192	112.0	15.0	11.8
	Ave.	13.3	6.5	201	119.8	15.0	12.1
B2478	1	12.6	9.2	192	75.2	15.0	14.2
	2	12.6	8.6	203	126.4	16.0	10.3
	3	13.4		183	108.0	15.0	17.2
	Ave.	12.9	8.9	193	103.2	15.3	13.9
B2479	1	12.6	Cells	192	Cells	17.0	Cells
	2	15.0	no	189	no	18.0	no
	3	13.0	good	183	good	19.0	good
	Ave.	13.5	-----	188	-----	18.0	-----
B2480	1	19.0	8.8	200	124.0	16.0	14.7
	2	19.0		208	120.7	16.0	14.9
	3	19.2		192	124.0	16.0	12.0
	Ave.	19.1	8.8	200	122.9	16.0	13.9
B2611	1	14.4	Cells	230	Cells	27.0	Cells
	2	12.8	no	246	no	28.0	no
	3	13.4	good	232	good	30.0	good
	Ave.	13.5	-----	236	-----	28.3	-----

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FIGURE 3

Leclanche Type "D" Cells Stored At 113° F. (Construction)

Storage time before initial testing at 70° F.		2 weeks at 70°F - 50% R.H.		
Storage time for cells stored at 113°F (Tested at 70°F)		1 month at 70°F - 50% R.H. 1 year at 113°F - 95% R.H.		
Lot No.	Mix Formulation	Separator	Subseal	Seal
B3178	100% African ore 7/1 - ore/black	Olin Starch Formulation #2 - 0.3% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> as inhibitor	Amprol wax	Bakelite cap
B3179	100% African ore 7/1 - ore/black	Olin Starch Formulation #3 - 0.25% HgCl <sub>2</sub> as inhibitor	"	"
B3180	20% Light Hydrate 80% African ore 7/1 - ore/black	Olin Starch Formulation #2 - 0.25% HgCl <sub>2</sub> as inhibitor	"	"
B3328	100% Cryptomelane (HCl - Lt. Hyd. leach) 7/1 - ore/black	Starch - flour paste 0.25% HgCl <sub>2</sub> as inhibitor	"	Polystyrene cap
B3332	30% Crypt. (HCl - Lt. Hyd. leach) - 70% Afr. ore - ore/black - 7/1	"	"	"
B3339	30% Crypt. (KCl - Lt. Hyd. leach) - 70% Afr. 7/1 - ore/black	"	"	"
B3344	30% Crypt. (NH <sub>4</sub> Cl - Lt. Hyd. leach) - 70% Afr. 7/1 - ore/black	"	"	"
B3547	100% Crypt. (ZnCl <sub>2</sub> - Lt. Hyd. leach) 7/1 - ore/black	"	"	"
B3351	30% Crypt. (ZnCl <sub>2</sub> - Lt. Hyd. leach) - 70% Afr. 7/1 - ore/black	"	"	"

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FIGURE 3 (cont.)

Lot No.	Mix Formulation	Separator	Subseal	Seal
B3697	100% Crypt. (ZnCl <sub>2</sub> - western Electro #18 leach) 7/1 - ore/black	Starch - flour paste 0.25% HgCl <sub>2</sub> as inhibitor	Amprol wax	Polystyrene cap
B3701	30% Crypt. (ZnCl <sub>2</sub> - W.E. #18 leach) - 70% African 7/1 - ore/black	"	"	"
B3704	100% Crypt. (NH <sub>4</sub> Cl - W.E. leach) 7/1 - ore/black	"	"	"
B3708	30% Crypt. (NH <sub>4</sub> Cl-W.E. #18 leach) - 70% Afr. 7/1 ore/black	"	"	"
B4609	30% Crypt. (HCl - Lt. Hyd. leach) - 70% Afr. 7/1 - ore/black	"	"	"
B4610	30% Crypt. (HCl - Lt. Hyd. leach) - 70% Afr. 7/1 - ore/black	Olin starch formulation #2 - 0.25% HgCl <sub>2</sub> as inhibitor	"	"
B4611	30% Crypt. (ZnCl <sub>2</sub> - Lt. Hyd. leach) - 70% Afr. 7/1 - ore/black	Starch - flour paste 0.25% HgCl <sub>2</sub> as inhibitor	"	"

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FIGURE 3A

Leclanche Type "D" Cells Stored at 113° F. (Capacity)

Lot No.	Test Results						
	Cell No.	BA 30 (days)		BA 8 (hours)		BA 408/U (hours)	
		Initial	1 yr. at 113°F	Initial	1 yr. at 113°F	Initial	1 yr. at 113°F
B3178	1	17.0	Cells no good	156.0	58.7	25.0	13.5
	2	15.4		158.0	100.0	25.0	9.5
	3	17.4		160.0	70.0	25.0	
	Ave	16.6		158.0	76.7	25.0	11.5
B3179	1	17.0	5.0	208.0	Cells	25.0	Cells
	2	15.8	2.8	212.0	no	26.0	no
	3	17.4		227.0	good	26.0	good
	Ave.	16.6	3.9	216.0		25.7	
B3180	1	18.2	Cells no good	240.0	201.6	30.0	14.3
	2	17.6		240.0	172.6	31.0	9.8
	3	16.6		240.0	184.0	30.0	13.3
	Ave.	17.5		240.0	186.1	30.3	12.8
B3328	1	12.6	Cells no good	237.0	64.0	30.0	4.0
	2	13.0		244.0	54.4	31.0	4.0
	3	12.6		222.0		27.0	4.0
	Ave.	12.7		234.0	59.2	29.3	4.0
B3332	1	18.2	Cells no good	228.0	88.0	26.0	14.7
	2	18.2		208.0	106.7	25.0	10.3
	3	17.5		220.0	77.3	27.0	13.3
	Ave.	17.9		219.0	90.7	26.0	12.8
B3339	1	15.8	5.6	213.0	134.2	27.0	16.0
	2	17.0	7.2	221.0	120.0	20.0	16.7
	3	18.0		195.0	104.7	28.0	
	Ave.	16.9	6.4	213.0	119.6	25.0	16.3
B3344	1	16.8	6.0	168.0	131.2	19.0	10.0
	2	14.8	6.2	196.0	108.0	20.0	15.0
	3	15.6	7.4	168.0	84.4	19.0	12.0
	Ave.	15.7	6.5	177.0	107.9	19.3	12.3
B3347	1	15.2	Cells no good	167.0	60.8	29.1	11.7
	2	15.6		125.0	136.0	29.5	11.6
	3	16.6		181.0	96.0	27.5	12.0
	Ave.	15.8		158.0	97.6	28.7	11.8

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FIGURE 3 A (cont.)

Lot No.	Test Results						
	Cell No..	BA 30 (days)		BA 8 (hours)		BA 408/U (hours)	
		Initial	1 yr. at 113°F	Initial	1 yr. at 113°F	Initial	1 yr. at 113°F
B3351	1	16.2	8.6	199.0	85.7	27.0	11.8
	2	19.2	5.6	236.0	129.5	18.0	11.7
	3	15.2	8.4	228.0	184.0	26.0	11.3
	Ave.	17.5	7.5	221.0	133.1	23.7	11.6
B3697	1	23.9	6.0	312.0	130.0	48.0	17.3
	2	24.4	5.8	296.0	136.0	47.0	14.7
	3	24.4		296.0	83.1	48.0	
	Ave.	24.2	5.9	301.0	116.4	47.6	16.0
B3701	1	18.2	8.2	287.0	200.0	26.0	15.6
	2	17.2	8.0	268.0	126.8	26.0	17.4
	3	17.4		251.0	208.0	26.0	16.0
	Ave.	17.6	8.1	269.0	178.2	26.0	16.3
B3704	1	9.6	4.6	349.0	160.0	32.0	Cells no good
	2	6.6	9.2	360.0	160.0	48.0	
	3	8.8		344.0		50.0	
	Ave.	8.3	6.9	351.0	160.0	43.3	
B3708	1	19.2	7.6	272.0	129.1	29.0	15.4
	2	19.6	9.0	267.0	208.0	29.0	11.6
	3	18.4	7.6	278.0	125.7	29.0	11.6
	Ave.	19.1	8.1	272.0	154.2	29.0	12.9
B4609	1	15.8	7.0	216.0	102.1	27.0	9.1
	2	14.4	7.4	195.0	100.8	22.0	14.3
	3	18.8	6.8	229.0	91.7	25.9	12.0
	Ave.	16.3	7.1	213.0	98.2	25.0	11.8
B4610	1	18.8	7.0	248.0	131.2	29.1	16.0
	2	14.8	7.4	220.0	136.0	30.5	15.6
	3	15.8	6.8	224.0	96.0	28.3	16.6
	Ave.	16.5	7.1	230.0	121.1	29.3	16.1
B4611	1	17.6	8.4	243.0	131.6	27.7	16.0
	2	14.8	7.6	245.0	97.6	26.8	18.4
	3	15.8	8.2	244.0	136.0	27.3	12.7
	Ave.	16.1	8.1	244.0	121.7	27.3	15.7

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FIGURE 4

LeClanche' Type "D" Cells For Storage At 113° F. (Construction)

Storage Time Before Initial Testing At 70° F.		2 weeks at 70° F. - 50% R.H.		
Storage Time For Cells Stored At 113° F. (Tested at 70° F.)		1 month at 70° F. - 50% R.H. 1 year at 113° F. - 95% R.H.		
Lot No.	Mix Formulation	Separator	Subseal	Seal
C2327	100% African Ore 7/1 - ore/black 1.0% BaCrO <sub>4</sub>	Starch - flour paste - 0.30% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> as inhibitor	Amprol wax	Polysty- rene cap
C2330	100% African Ore 7/1 - ore/black	Starch - flour paste - 0.30% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> as inhibitor	Amprol wax	Polysty- rene cap
C2333	100% African Ore 7/1 - ore/black	Starch - flour paste - 0.30% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> and 0.20% Antaron R155	Amprol wax	Polysty- rene cap
C2336	100% African Ore 7/1 - ore/black	Starch - flour paste - 0.20% Antaron R155 as inhibitor	Amprol wax	Polysty- rene cap
C2339	100% African Ore 7/1 - ore/black	Starch - flour paste - HgCl <sub>2</sub> and 0.20% Ant- aron R155 as inhibitor	Amprol wax	Polysty- rene cap
C2342	100% African Ore 7/1 - ore/black	Starch - flour paste - 1.0% Protein R <sub>2</sub> E-270 without HgCl <sub>2</sub> - inhibitor	Amprol wax	Polysty- rene cap
C2345	100% African Ore 7/1 - ore/black	Starch - flour paste - 1.0% Denatured Gluten and no HgCl <sub>2</sub> -inhibitor	Amprol wax	Polysty- rene cap
C2348	100% African Ore 7/1 - ore/black 1.0% BaCrO <sub>4</sub>	Starch - flour paste - 0.30% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> inhibitor graphite treated rods	Amprol wax	Polysty- rene cap
C2351	100% African Ore 7/1 - ore/black 1.0% BaCrO <sub>4</sub>	Starch - flour paste - paraffin treated rods	Amprol wax	Polysty- rene cap

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FIGURE 4A (Cont.)

LeClanche' Type "D" Cells Stored At 113° F. (Capacity Results)

Lot No.	Aver. Cell	Test Results					
		BA-30 (days)		BA-8 (hours)		BA-408/U (hours)	
		Initial	After 1 yr. @113°	Initial	After 1 yr. @113°	Initial	After 1 yr. @113°
G2327	Aver.	11.7	9.1	181.6	118.0	23.8	20.7
G2330	Aver.	10.2	6.8	180.0	145.0	20.0	16.4
G2333	Aver.	10.3	5.3	161.2	112.0	22.7	12.6
G2336	Aver.	11.3	7.8	175.0	162.0	24.9	9.9
G2339	Aver.	12.9	7.2	213.0	155.0	23.1	13.8
G2342	Aver.	12.1	9.1	195.0	152.0	21.7	13.3
G2345	Aver.	12.7	8.3	203.8	171.0	24.5	14.9
G2348	Aver.	11.5	7.8	176.0	140.0	25.6	18.9
G2351	Aver.	12.7	7.5	232.5	173.0	23.1	18.8

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CONSTRUCTION AND CAPACITY RESULTS OF CELLS

STORED AT

130° F.

FOR 3 MONTHS AT 50% R.H.

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FIGURE 5

Leclanche Type "D" Cells For Storage At 130°F (Construction)

Storage time before initial testing at 70°F		2 weeks at 70°F, 50% R.H.		
Storage time for cells on 130°F storage (tested at 70°F)		2 weeks at 70°F, 50% R.H. 3 months at 130°F, 50% R.H.		
Lot No.	Mix Formulati on	Separator	Subseal	Seal
C856	100% African ore 7/1 - ore/black 10% Sal ammoniac	Potato starch, corn starch, flour paste 0.25% HgCl <sub>2</sub>	Amprol wax	Poly-styrene cap
C857	100% African ore 7/1 - ore/black 10% Sal ammoniac	Olin starch formulation #2 - 0.25% HgCl <sub>2</sub>	Amprol wax	Poly-styrene cap
C858	100% African ore 7/1 - ore/black 20% Sal ammoniac	Potato starch, corn starch, flour paste 0.25% HgCl <sub>2</sub>	Amprol wax	Poly-styrene cap
C859	100% African ore 7/1 - ore/black 20% Sal ammoniac	Olin Starch formulation #2 - 0.25% HgCl <sub>2</sub>	Amprol wax	Poly-styrene cap
C860	30% Lt. Hydrate 70% African ore 7/1 - ore/black	Potato starch, corn starch, flour paste 0.25% HgCl <sub>2</sub>	Amprol wax	Poly-styrene cap
C861	30% Lt. Hydrate 70% African ore 7/1 - ore/black	Olin starch formulation #2 - 0.25% HgCl <sub>2</sub>	Amprol wax	Poly-styrene cap
C862	30% Western Electro ore 70% African ore 7/1 - ore/black	Potato starch, corn starch, flour paste 0.25% HgCl <sub>2</sub>	Amprol wax	Poly - styrene cap
C863	30% Western Electro ore 70% African ore 7/1 - ore/black	Olin starch formulation #2 - 0.25% HgCl <sub>2</sub>	Amprol wax	Poly-styrene cap
C864	30% Burgess Electro ore 70% African ore 7/1 - ore/black	Potato starch, corn starch, flour paste 0.25% HgCl <sub>2</sub>	Amprol wax	Poly-styrene cap
C865	30% Burgess Electro ore 70% African ore 7/1 - ore/black	Olin starch formulation #2 - 0.25% HgCl <sub>2</sub>	Amprol wax	Poly-styrene cap
C873	30% Burgess Chem ore 70% African ore 7/1 - ore/black	Potato starch, corn starch, flour paste 0.25% HgCl <sub>2</sub>	Amprol wax	Poly-styrene cap

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FIGURE 5

Lot No.	Mix Formulation	Separator	Subseal	Seal
C874	30% Burgess Chem. ore 70% African ore 7/1 - ore/black	Olin starch formulation #2 - 0.25% HgCl <sub>2</sub>	Amprol wax	Poly-styrene cap
C875	100% African ore 7/1 - ore/black 10% Sal ammoniac	Corn starch, potato starch, flour paste 0.25% HgCl <sub>2</sub>	Amprol wax	Poly-styrene cap
C876	100% African ore 7/1 - ore/black 10% Sal ammoniac	Olin Starch Formulation #2 0.25% HgCl <sub>2</sub>	Amprol wax	Poly-styrene cap
C877	100% African ore 7/1 - ore/black 20% Sal ammoniac	Corn starch, potato starch, flour paste 0.25% HgCl <sub>2</sub>	Amprol wax	Poly-styrene cap
C878	100% African ore 7/1 - ore/black 20% Sal ammoniac	Olin starch formulation #2 0.25% HgCl <sub>2</sub>	Amprol wax	Poly-styrene cap

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FIGURE 5A

Leclanche Type " " Cells For Storage at 130° F (Capacity results)

Lot No.	Test Results						
	Cell No.	BA-30 (days)		BA-8 (hours)		BA-408 (hours)	
		Initial	3 mos. at 130°F	Initial	3 mos. at 130°F	Initial	3 mos. at 130°F
C856	1	15.8	8.8	227.2	160.0	26.8	14.3
	2	16.2	7.2	232.0	180.0	26.8	13.7
	3	16.8	10.0	232.0	104.0	25.5	12.0
	Ave.	16.3	8.9	230.4	146.0	26.3	13.3
C857	1	12.0	4.8	168.0	118.0	26.1	13.3
	2	12.0	7.2	184.0	107.2	25.6	14.7
	3	11.8	4.6	168.0	92.8	26.0	17.3
	Ave.	11.9	5.5	173.0	106.0	25.9	15.1
C858	1	13.8	7.8	203.4	130.8	20.0	17.0
	2	13.0	6.8	210.4	125.7	26.0	17.8
	3	13.2	8.2	219.4	118.4	26.2	12.0
	Ave.	13.4	7.6	211.0	124.9	24.1	15.6
C859	1	15.4	5.6	200.9	131.2	26.1	12.0
	2	15.0	2.4	202.0	88.0	26.4	15.2
	3	15.0	4.8	202.0	106.7	26.5	11.0
	Ave.	15.1	4.3	201.8	108.6	26.3	12.7
C860	1	19.6	8.0	272.0	110.4	31.7	16.0
	2	21.4	7.2	267.2	134.9	31.4	19.1
	3	20.8		276.8		30.7	
	Ave.	20.6	7.6	272.0	122.6	31.3	17.5
C861	1	17.0	9.4	242.7	110.6	29.2	10.0
	2	14.4	8.0	242.3	91.2	31.7	17.6
	3	16.0		221.3	113.1	31.6	
	Ave.	15.8	8.7	235.4	104.9	30.2	13.8
C862	1	16.8	7.0	245.3	105.6	29.8	16.0
	2	17.8	6.8	250.7	116.0	28.0	15.7
	3	16.6	6.4	256.0	128.0	26.4	11.8
	Ave.	17.1	6.7	250.4	116.5	28.1	14.5
C863	1	11.0	4.6	184.0	96.0	26.7	16.8
	2	12.2		184.0	104.0	27.1	
	3						
	Ave.	11.6	4.6	184.0	100.0	26.9	16.8
C864	1	13.6	7.6	266.5	117.5	26.6	18.3
	2	14.6	6.4	241.5	107.2	27.4	17.0
	3	13.0		264.0	92.0	27.8	11.3
	Ave.	13.7	7.0	257.5	105.5	27.3	15.5

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FIGURE 5A (cont.)

Lot No.	Test Results						
	Cell No.	BA-30 (days)		BA-8 (hours)		BA-408 (hours)	
		Initial	3 mos. at 130°F	Initial	3 mos. at 130°F	Initial	3 mos. at 130°F
C865	1	10.0	6.0	178.7	96.0	28.9	13.3
	2	9.6		184.0	112.0	28.6	8.0
	3	9.6		178.7	121.6	28.7	19.5
	Ave.	9.7	6.0	180.5	109.9	28.7	13.2
C873	1	15.2	7.8	232.0	116.0	25.5	15.5
	2	14.2	7.4	224.0	126.8	25.9	17.1
	3	16.2	7.0	232.0	129.5	26.4	15.7
	Ave.	15.2	7.4	229.0	124.1	25.9	16.1
C874	1	14.0	6.2	178.0	99.3	25.8	17.5
	2	10.4	7.4	160.0	126.4	25.2	16.7
	3	11.0		164.0	101.7	25.7	
	Ave.	11.8	6.8	167.0	109.1	25.5	17.1
C875	1	16.6	9.0	240.0	127.3	27.8	11.3
	2	15.4	8.4	244.0	116.8	26.4	15.0
	3	15.6	7.8	245.3	94.9	27.8	14.0
	Ave.	15.9	8.4	243.1	113.0	27.3	13.4
C876	1	14.0	7.0	184.0	104.0	26.5	16.0
	2	11.8	2.8	192.0	92.8	24.0	13.6
	3	12.0			72.0	27.5	
	Ave.	12.6	4.9	188.0	89.6	26.0	14.8
	1	16.0	9.0	222.0	125.1	23.6	12.0
	2	16.0	9.0	216.0	130.0	25.5	12.0
	3	16.8	7.6	220.0	122.0	23.2	12.0
	Ave.	16.3	8.5	219.0	125.7	24.1	12.0
C878	1	15.2	9.6	216.0	144.0	24.0	16.0
	2	15.6	6.4	210.0	157.3	24.7	12.0
	3	15.2	8.2	216.0	94.9	24.7	14.5
	Ave.	15.3	8.1	214.0	132.1	24.5	14.2

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FIGURE 6

Leclanche Type "D" Cells Stored At 130°F (Construction)

Storage time before initial testing at 70° F.		2 weeks at 70°F , 50% R.H.		
Storage time for cells stored at 130°F (Tested at 70°F)		2 weeks at 70°F , 50% R.H. 3 months at 130°F , 50% R.H.		
Lot No.	Mix Formulation	Separator	Subseal	Seal
C2328	100% African ore 7/1 - ore/black 1.0% BaCrO <sub>4</sub>	Starch - flour paste 0.3% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> as inhibitor	Amprol wax	Heat res. polystyrene cap
C2331	100% African ore 7/1 - ore/black	"	"	"
C2334	100% African ore 7/1 - ore/black	Starch - flour paste 0.3% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> + 0.1% Antaron R155	"	"
C2337	100% African ore 7/1 - ore/black	Starch - flour paste 0.1% Antaron R155 as inhibitor	"	"
C2340	100% African ore 7/1 - ore/black	Starch - flour paste 0.25% HgCl <sub>2</sub> + 0.1% Ant. R155 as inhibitor	"	"
C2343	100% African ore 7/1 - ore/black	Starch - flour paste 1.0% Protein R2E-570 as inhibitor	"	"
C2346	100% African ore 7/1 - ore/black	Starch - flour paste 1.0% Denatured Gluten as inhibitor	"	"
C2349	100% African ore 7/1 - ore/black 1.0% BaCrO <sub>7</sub>	Starch - flour paste 0.3% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> as inhibitor	"	"
C2352	100% African ore 7/1 - ore/black 1.0% BaCrO <sub>7</sub>	Starch - flour paste 0.3% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> as inhibitor	"	"
C2797	100% African ore 7/1 - ore/black	Starch - flour paste 0.25% HgCl <sub>2</sub> + 0.1% Ant. R155 as inhibitor	"	"

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FIGURE 6 A

Lot No.	Test Results						
	Cell No.	BA 30 (days)		BA 8 (Hours)		BA 408/U (hours)	
		Initial	3 mos. at 130° F	Initial	3 mos. at 130° F	Initial	3 mos. at 130° F
C2328	1	10.8	4.2	165.3	112.0	19.7	14.5
	2	10.8	7.2	166.4	117.3	19.7	11.5
	3	10.4	7.2	166.7	116.4	18.9	12.8
	Ave.	10.7	6.2	166.1	115.2	19.4	12.9
C2331	1	9.6	3.6	160.0	84.0	21.4	11.6
	2	8.8	6.6	176.0	48.0	21.5	9.0
	3	10.6	4.8	168.0	101.3	22.5	8.4
	Ave.	9.6	5.0	168.0	77.7	21.8	9.7
C2334	1	10.4	8.2	139.0	121.6	21.2	11.0
	2	10.0	7.0	142.4	122.7	20.0	10.9
	3	10.2	7.4	142.4	136.0	20.9	10.9
	Ave.	10.2	7.5	141.3	126.7	20.7	10.9
C2337	1	10.8	6.0	156.0	90.7	18.0	11.1
	2	11.2	3.6	160.0	120.0	18.8	10.4
	3	10.6	4.4	154.7	88.0	18.0	10.3
	Ave.	10.9	4.6	156.9	99.5	18.3	10.6
C2340	1	12.6	5.4	198.4	78.4	17.7	10.7
	2	12.2	6.0	180.0	74.3	18.3	10.3
	3	12.8	5.8	184.0	90.7	17.8	10.6
	Ave.	12.5	5.7	187.5	81.1	17.9	10.5
C2343	1	11.6	6.2	177.7	100.6	17.5	10.9
	2	11.2	6.4	183.0	120.7	17.8	10.4
	3	11.0	4.6	191.0		17.2	9.8
	Ave.	11.3	5.7	183.9	110.6	17.5	10.3
C2346	1	12.6	5.6	192.0	168.0	22.6	12.0
	2	12.4	8.6	192.0	152.0	22.0	14.1
	3	12.2	11.0	200.0	101.3	21.4	12.0
	Ave.	12.4	8.4	195.0	140.4	22.0	12.7

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FIGURE 6A (cont.)

Lot No.	Test Results						
	Cell No.	BA 30 (days)		BA 8 (hours)		BA 408/U (hours)	
		Initial	3 mos. at 130°F	Initial	3 mos. at 130°F	Initial	3 mos at 130°F
C2349	1	10.2	6.0	164.0	116.4	19.3	12.5
	2	10.2	8.8	165.3	118.0	18.9	14.2
	3	11.2	5.2	164.0	130.0	19.5	14.6
	Ave.	10.5	6.6	164.4	121.4	19.2	13.7
C2352	1	12.6	8.6	220.0	160.0	21.1	11.4
	2	12.0	7.2	204.0	148.0	22.0	11.4
	3	12.2		202.7	116.8	22.3	10.4
	Ave.	12.3	7.9	208.9	141.6	21.8	11.0
C2797	1	14.6	7.8	240.0	168.0	25.5	14.0
	2	14.8	7.6	228.0	154.7	26.0	11.6
	3	14.6	7.6	232.0	145.6	25.7	15.3
	Ave.	14.6	7.7	233.0	156.1	25.7	13.6

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CONSTRUCTION AND CAPACITY RESULTS OF CELLS

STORED AT

160° F.

FOR 2 WEEKS AT 50% R.H.

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FIGURE 7

LeClanché Type "D" Cells For Storage At 160°F (Construction)

Storage time before initial testing at 70°F		2 weeks at 70°F - 50% R.H.		
Storage time for cells on 160°F storage (tested at 70°F)		2 weeks at 70°F - 50% R.H. 2 weeks at 160°F - 50% R.H.		
Lot No.	Mix Formulation	Separator	Subseal	Seal
B3160	100% African ore 7/1 - ore/black	Flour - starch paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polystyrene cap
B3161	100% African ore 7/1 - ore/black	Special starch paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polystyrene cap
B3162	100% African ore 7/1 - ore/black 1.0% BaCrO <sub>4</sub>	Flour - starch paste 0.3% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> as inhibitor	amprol wax	polystyrene cap
B3163	100% African ore 7/1 ore/black 1.0% BaCrO <sub>4</sub>	Special starch paste 0.3% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> as inhibitor	amprol wax	polystyrene cap
B3164	100% African ore 7/1 - ore/black 0.5% CrO <sub>3</sub>	Flour - starch paste 0.3% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> as inhibitor	amprol wax	polystyrene cap
B3165	100% African ore 7/1 - ore/black 0.5% CrO <sub>3</sub>	Special starch paste 0.3% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> as inhibitor	amprol wax	polystyrene cap
B3166	100% African ore 7/1 ore/black 0.5% CrO <sub>3</sub>	Flour - starch paste 0.3% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> as inhibitor	amprol wax	polystyrene cap
B3167	100% African ore 7/1 - ore/black 0.5% CrO <sub>3</sub>	Special starch paste Cronaked cans 0.3% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>	amprol wax	polystyrene cap

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FIGURE 7 (cont.)

Lot No.	Mix Formulation	Separator	Subseal	Seal
B3168	100% African ore 7/1 - ore/black 1.0% BaCrO <sub>4</sub>	Flour - starch paste Cronaked cans 0.3% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>	amprol wax	polysty- rene cap
B3169	100% African ore 7/1 - ore/black 1.0% BaCrO <sub>4</sub>	Special starch paste Cronaked cans 0.3% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>	amprol wax	polysty- rene cap
B3170	100% African ore 7/1 - ore/black	Special starch - flour paste - 0.3% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> as inhibitor	amprol wax	polysty- rene cap
B3171	100% African ore 7/1 - ore/black	Special starch-flour paste - 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polysty- rene cap
B3173	100% African ore 7/1 - ore/black 1.0% BaCrO <sub>4</sub>	Special starch paste 0.3% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> as inhibitor	amprol wax	polysty- rene cap
B3174	100% Western Electro ore - 7/1 ore/black	Special starch paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polysty- rene cap
B3175	50% Western Electro 50% African ore 7/1 - ore/black	Special starch paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polysty- rene cap
B3176	33% Light Hydrate 67% African ore 7/1 - ore/black	Special starch paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polysty- rene cap
B3177	100% African ore 7/1 - ore/black	Starch - flour paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	hard wax
B3327	100% Crypt. (H <sub>2</sub> O Lt. Hyd.) 7/1 - ore/black	Starch - flour paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polysty- rene cap

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FIGURE 7 (cont.)

Lot No.	Mix Formulation	Separator	Subseal	Seal
B3330	30% Cryptomelane 70% African ore 7/1 - ore/black	Starch - flour paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polystyrene cap
B3334	100% Crypt. (KCl - Lt. Hyd.) 7/1 - ore/black	Starch - flour paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polystyrene cap
B3337	30% Cryptomelane 70% African ore 7/1 - ore/black	Starch - flour paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polystyrene cap
B3342	30% Crypt. (NH <sub>4</sub> Cl - Lt. Hyd.) 70% Afr. ore 7/1 - ore/black	Starch - flour paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polystyrene cap
B3346	100% Crypt. (ZnCl <sub>2</sub> - Lt. Hyd.) 7/1 - ore/black	Starch - flour paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polystyrene cap
B3349	30% Cryptomelane 70% African ore 7/1 - ore/black	Starch - flour paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polystyrene cap
B3696	100% Crypt. (ZnCl <sub>2</sub> - W.E. ore) 7/1 - ore/black	Starch - flour paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polystyrene cap
B3699	30% Cryptomelane 70% African ore 7/1 - ore/black	Starch - flour paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polystyrene cap
B3703	100% Crypt. (NH <sub>4</sub> Cl - Western Electro ore) 7/1 - ore/black	Starch - flour paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polystyrene cap
B3706	30% Cryptomelane 70% African ore 7/1 - ore/black	Starch - flour paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polystyrene cap

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FIGURE 7 (cont.)

Lot No.	Mix Formulation	Separator	Subseal	Seal
B4582	50% Crypt. (NH <sub>4</sub> Cl - W.E. ore) - 50% Afr. ore -- 7/1 - ore/black	Starch - flour paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polystyrene cap
B4737	100% African ore 7/1 - ore/black	Starch - flour paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polystyrene cap
B4846	30% Crypt. (ZnCl <sub>2</sub> - W.E. ore) - 70% Afr. ore - 7/1 - ore/black	Starch - flour paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polystyrene cap
B4911	30% Western Electro 70% African ore 7/1 - ore/black	Starch - flour paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polystyrene wax
C787	100% African ore 7/1 - ore/black	Starch - flour paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polystyrene cap
C788	100% African ore 7/1 - ore/black	Special starch paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polystyrene cap
B4738	100% African ore 7/1 - ore/black	Starch - flour paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polystyrene cap
B4739	100% African ore 7/1 - ore/black	Special starch paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polystyrene cap
B4847	30% Crypt. (ZnCl <sub>2</sub> - W.E. ore) 70% African Ore - 7/1 - ore/black	Starch - flour paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polystyrene cap
C1623	100% African ore 7/1 - ore/black	Starch - flour paste 0.3% HgCl <sub>2</sub> as inhibitor	amprol wax	polystyrene cap

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FIGURE 7A

LeClanché Type "D" Cells For Storage At 160°F (Capacity)

Lot No.	Cell No.	Test Results					
		BA-30 (days)		BA-8 (hours)		BA-408/U (hours)	
		Initial	2 wks. at 160° F.	Initial	2 wks. at 160° F.	Initial	2 wks. at 160° F.
B3160	1	13.6	5.8	220	101	19.0	11.0
	2	13.4	6.4	178	107	18.0	11.0
	3	14.0	5.8	190	113	20.0	10.0
	4	14.0	5.2	190	97		10.0
	5				113		11.0
	Ave.	13.8	5.8	195	106	19.0	10.6
B3161	1	14.2		178	58.0	19.0	3.0
	2	13.4		192	79	20.0	6.0
	3	14.0	2.4	192	60	19.0	9.0
	4				60		1.0
	Ave.	13.9	2.4	187	64.2	19.3	4.8
B3162	1	11.2	4.6	162	24.0	21.0	13.0
	2	11.0	5.2	172	64.0	21.0	9.0
	3	11.2	5.6	168	80.9	21.0	9.0
	4	11.4	3.2	168	61.0	22.0	10.0
	5		2.0				
	Ave.	11.2	4.1	168	58.0	21.3	10.3
B3163	1	11.2	2.6	161	129.0	Cells discharge thru wrong drain	12.0
	2	11.4	2.6	157	120.0		10.0
	3	11.4	4.8	166	120.0		10.0
	4	11.4	5.0		144.0		10.0
	5		2.2		116.0		10.0
	Ave.	11.4	3.4	161	126.0	-----	10.4
B3164	1	11.6	Cells no good	168	80.0	22.0	6.0
	2	11.6		168	68.0	21.0	8.0
	3	11.4		168	40.0	22.0	10.0
	4				50.3		
	Ave.	11.6	-----	168	59.5	21.7	8.0

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FIGURE 7A (cont.)

Lot No.	Test Results						
	Cell No.	BA-30 (days)		BA-8 (hours)		BA-408/U (hours)	
		Initial	2 wks. at 160° F.	Initial	2 wks. at 160° F.	Initial	2 wks at 160° F.
B3165	1	12.4	3.0	166	77.0	23.0	11.0
	2	12.2	1.0	168	99.0	23.0	10.0
	3	12.2	---	166	99.0	23.0	11.0
	4		2.4		102.0		9.0
	5		4.0		108.0		11.0
	Ave.	12.3	2.6	166.7	97.0	23.0	10.4
B3166	1	12.2	Cells no good	156	53.3	23.0	4.0
	2	13.6		165	64.0	23.0	---
	3	13.0			15.0	23.0	---
	4				44.0		
	Ave.	12.9	-----	160	44.1	23.0	4.0
B3167	1	11.0	2.2	177	81.7	25.0	10.8
	2	12.0	2.0	179	99.7	25.0	7.1
	3	11.8	3.8	177	89.0	26.0	9.7
	4		3.0		45.3		11.5
	5		1.3		88.2		
	Ave.	11.6	2.5	178	81.0	25.3	9.8
B3168	1	12.8	2.0	202	88.0	25.0	9.8
	2	12.2	---	197	47.0	25.0	9.6
	3	12.4	7.2	211	88.0	25.0	
	4		7.6		107.0		
	Ave.	12.5	7.4	203	82.5	25.0	9.7
B3169	1	12.6	4.0	198	109.7	25.0	3.0
	2	13.4	5.0	189	88.0	25.0	4.0
	3	12.6	5.0	192	54.4	26.0	8.0
	4	11.6	5.0	192	136.7	25.0	10.0
	5		2.0		48.0		
	Ave.	12.6	4.3	193	88.0	25.2	6.3

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FIGURE 7 A (cont.)

Lot No.	Test Results						
	Cell No.	BA-30 (days)		BA-8 (hours)		BA-408/U (hours)	
		Initial	2 wks at 160° F.	Initial	2 wks at 160° F.	Initial	2 wks at 160° F.
B3170	1	11.6	2.2	181.3	56.0	25.5	4.0
	2	12.4	4.4	184.0	90.7	25.5	9.0
	3	12.6	4.2	184.0	101.3	25.5	9.0
	4	12.4		184.0	54.3		
	5				40.0		
	Ave.	12.3	3.6	183.3	68.5	25.5	7.3
B3171	1	16.2	3.0	220.0	88.0	29.0	Cells no good
	2	18.0	7.4	222.0	88.0	27.0	
	3	17.8		220.0		25.0	
	4	17.3	5.2	221.0	88.0	27.0	-----
B3173	1	13.0	Cells no good	188.0	48.0	NO results	Cells no good
	2	11.6		185.0	61.3		
	3	12.2		184.0	37.3		
	Ave.	12.3	-----	186.0	49.0	-----	-----
B3174	1	24.8	5.2	324.0	152.0	45.0	Cells no good
	2	24.6	3.2	293.0		47.0	
	3	24.8		264.0		46.0	
	Ave.	24.7	4.2	294.0	152.0	46.0	-----
B3175	1	15.0	Cells no good	252.0	64.0	31.0	16.0
	2	14.2		230.0	116.0	32.0	12.0
	3			249.0	88.0	31.0	17.0
	4				120.0		
	Ave.	14.6	----	244.0	90.4	31.3	15.0

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FIGURE 7 A (cont.)

Lot No.	Test Results						
	Cell No.	BA-30 (days)		BA-8 (hours)		BA-408/U (hours)	
		Initial	2 wks at 160° F.	Initial	2 wks at 160° F.	Initial	2 wks at 160° F.
B3176	1	20.6	6.0	233.0	53.3	32.0	6.0
	2	17.0		235.0	24.0	31.7	
	3	19.4		228.0	42.7	31.7	
	4	19.4		239.0	87.8	30.2	
	Ave.	19.1	6.0	234.0	52.0	31.4	6.0
B3177	1	No results	Cells no good	162.0	24.0	No results	Cells no good
	2			206.0	50.0		
	3			240.0	96.0		
	4			184.0	23.0		
	Ave.	-----	-----	198.0	56.3	-----	-----
B3327	1	9.6	1.4	210.0	54.4	21.0	4.0
	2	11.6	1.6	212.0	56.0	22.0	4.0
	3	12.0		225.0	58.7	22.0	6.0
	4					21.0	
	Ave.	11.1	1.5	216.0	56.4	21.5	4.7
B3330	1	13.2	Cells no good	182.0	2.1	17.5	1.0
	2	13.6		165.0	51.4	18.6	2.0
	3			172.0	44.9	16.9	
	Ave.	13.4	----	173.0	48.1	17.7	1.5
B3334	1	9.4	7.4	193.0	35.0	23.0	Cells no good
	2	11.0		193.0	24.0	21.0	
	3	9.2		182.0	29.0	20.0	
	4					24.0	
	Ave.	9.9	7.4	189.0	29.3	22.0	-----
B3337	1	13.0	Cells no good	193.0	35.0	19.0	4.0
	2	13.2		183.0	40.0	23.0	
	3	14.2		192.0	12.0	24.0	
	4					23.0	
	Ave.	13.5	-----	190.0	37.5	22.3	4.0

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FIGURE 7A (cont.)

Lot No.	Test Results						
	Cell No.	BA-30 (days)		BA-8 (hours)		BA-408/U (hours)	
		Initial	2 wks. at 160° F.	Initial	2 wks at 160° F.	Initial	2 wks at 160° F.
B3342	1	12.6	3.4	115.0	52.6	16.0	8.0
	2	10.0	2.2	132.0	58.0	14.0	7.0
	3	14.2	3.6	128.0	72.0	15.0	5.0
	4					16.0	8.0
	Ave.	12.3	3.1	125.0	60.9	15.3	7.0
B3346	1	12.6	5.4	171.0	83.0	26.0	9.0
	2	14.0	4.8	174.0	88.0	26.0	9.0
	3	12.8	2.8	164.0	64.0	26.0	11.0
	4					26.0	10.0
	Ave.	13.1	4.3	170.0	78.0	26.0	9.0
B3349	1	15.8	6.8	195.0	81.0	16.4	9.0
	2	14.6	6.0	205.0	77.0	15.8	9.0
	3	14.6	6.4	195.0	78.0	16.9	10.0
	4					17.3	10.0
	Ave.	15.0	6.4	198.0	79.0	16.6	9.5
B3696	1	22.2	Cells	289.0	108.0	36.0	Cells
	2	20.8	no	273.0	42.0	39.0	no
	3	21.2	good	299.0	50.0	39.0	good
	4					39.0	
	Ave.	21.4	-----	287.0	67.0	38.2	-----
B3699	1	16.0	6.8	232	113.0	24.0	14.5
	2	17.4	7.6	240	142.0	23.0	14.0
	3	14.8	7.2	240	130.0	23.0	15.1
	4					23.0	15.4
	Ave.	16.1	7.2	237.0	128.0	23.2	14.7
B3703	1	4.8	Cells	243.0	88.0	10.0	Cells
	2	6.4	no	264.0		15.0	no
	3	4.2	good	324.0		12.0	good
	4					13.0	
	Ave.	5.1	-----	277.0	88.0	12.5	-----

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FIGURE 7 A (cont.)

Lot No.	Test Results						
	Cell No.	BA-30 (days)		BA-8 (hours)		BA-408/U (hours)	
		Initial	2 wks at 160° F.	Initial	2 wks at 160° F.	Initial	2 wks at 160° F.
B3706	1	17.4	8.0	229.0	144.0	25.0	13.0
	2	17.6	7.0	233.0	131.0	26.0	14.0
	3	19.2	8.6	256.0	108.0	26.0	13.0
	4						13.0
	Ave.	18.1	7.9	239.0	128.0	25.7	13.2
B4582	1	15.6	4.4	202.0	84.0	24.4	7.2
	2	15.6	4.6	208.0	98.7	26.6	5.5
	3	14.2	5.2	228.0	26.9	20.0	8.0
	Ave.	15.1	4.7	213.0	91.3	23.7	6.9
B4737	1	12.6	6.0	208.0	105.0	20.6	10.3
	2	13.2	6.2	190.0	109.0	21.3	10.7
	3	13.8	6.1	186.7	96.0	21.4	10.3
	Ave.	13.2	6.1	195.0	104.0	21.1	10.4
B4846	1	15.6	7.0	256.0	94.0	26.5	14.3
	2	14.8	7.0	238.4	124.0	26.8	16.0
	3	13.8	6.8	235.2	133.6	24.9	13.8
	4	14.6	3.6	250.7	126.1	26.2	15.7
	Ave.	14.7	6.1	245.0	117.0	26.1	14.9
B4911	1	16.8	8.2	192.0	112.4	20.0	13.0
	2	17.6	7.3	204.0	126.9	26.2	17.0
	3	15.2	6.0	164.0	85.3	26.2	18.0
	Ave.	16.5	7.1	187.0	108.0	24.1	16.0
C787	1	13.6	2.8	192.0	72.8	18.9	4.0
	2	12.8		194.0		18.2	
	3	12.8		194.0		18.7	
	Ave.	13.1	2.8	193.0	72.8	18.6	4.0
C788	1	13.6	4.0	176.0	84.4	19.4	10.2
	2	13.6	6.0	186.0	77.3	19.5	9.6
	3	13.0	2.8	186.0	83.2	19.5	4.0
	Ave.	13.4	4.3	183.0	80.6	19.5	9.9

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FIGURE 7A (cont.)

Lot No.	Test Results						
	Cell No.	BA-30 (days)		BA-8 (hours)		BA-408/U (hours)	
		Initial	2 wks at 160° F	Initial	2 wks at 160° F	Initial	2 wks at 160° F
B4738	1	12.8	5.0	196.0	96.0	21.8	10.9
	2	12.6	5.4	201.0	114.7	21.7	10.9
	3	12.4	5.2	208.0	82.0	21.4	10.3
	Ave.	12.6	5.2	202.0	97.6	21.6	10.7
B4739	1	12.4	3.2	198.4	118.0	23.3	wrong discharge
	2	13.0	6.4	192.0	96.0	21.9	
	3	12.5	6.0	185.8	99.3	22.9	
	Ave.	12.6	5.2	192.0	107.8	22.7	-----
B4847	1	13.6	5.6	232.0	112.0	27.0	8.0
	2	14.4	5.2	250.7	107.6	26.5	13.0
	3	15.6	4.2	226.7	94.9	27.2	11.2
	Ave.	14.5	5.0	237.0	104.8	26.9	10.7
C1623	1	14.0	9.8	220.0	155.1	18.5	11.8
	2	15.0	8.8	212.0	176.0	25.1	11.6
	3	13.4	8.4	236.0	136.0	22.0	11.6
	Ave.	14.1	9.0	223.0	155.7	21.9	11.7

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FIGURE 8

Leclanche Type "D" Cells Stored At 160° F (Construction)

Storage time before initial testing at 70° F		2 weeks at 70° F , 50% R.H.		
Storage time for cells stored at 160°F (tested at 70°F)		2 weeks at 70° F , 50% R.H. 2 weeks at 160° F, 50% R.H.		
Lot No.	Mix Formulation	Separator	Subseal	Seal
C2329	100% African ore 7/1 - ore/black 1.0% BaCrO <sub>4</sub>	Starch - flour paste 0.3% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> as inhibitor	Amprol wax	Heat res. polystyrene cap
C2332	100% African ore 7/1 - ore/black	"	"	"
C2335	100% African ore 7/1 - ore/black	Starch - flour paste 0.3% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> + 0.1% Antaron R 155	"	"
C2338	100% African ore 7/1 - ore/black	Starch - flour paste 0.1% Antaron R155 as inhibitor	"	"
C2341	100% African ore 7/1 - ore/black	Starch - flour paste 0.25% HgCl <sub>2</sub> + 0.1% Antaron R155	"	"
C2344	100% African ore 7/1 - ore/black	Starch - flour paste 1.0% Protein R2E-570 as inhibitor	"	"
C2347	100% African ore 7/1 - ore/black	Starch - flour paste 1.0% Denatured Gluten as inhibitor	"	"
C2350	100% African ore 7/1 - ore/black	Starch - flour paste 0.3% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> as inhibitor	"	"
C2353	100% African ore 7/1 - ore/black	"	"	"
C2798	100% African ore 7/1 - ore/black	Starch - flour paste 0.20% HgCl <sub>2</sub> + 0.1% Ant. as inhibitor	Polyethyl-Gasket no wax subseal	"

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FIGURE 8 (cont.)

Lot No.	Mix Formulation	Separator	Subseal	Seal
C2774	100% African ore 7/1 - ore/black	Starch - flour paste 0.25% HgCl <sub>2</sub> as inhibitor	Polyeth- ylene gasket - no wax	Heat res. polysty- rene cap
C2775	100% African ore 7/1 - ore/black	"	"	"
C2776	100% African ore 7/1 - ore/black	"	Polyethyl gasket + amprol wax	"
C3267	100% Cryptolite 7/1 - ore/black	"	polyethyl- ene gasket - no wax	"
C3268	100% Cryptolite 7/1 - ore/black	Olin starch formulation #2 - 0.25% HgCl <sub>2</sub> as inhibitor	"	"
C3271	30% Cryptolite - 70% African ore 7/1 - ore/black	Starch - flour paste 0.25% HgCl <sub>2</sub> as inhibitor	"	"
C3272	30% Cryptolite - 70% African ore 7/1 - ore/black	Olin starch formulation #2 - 0.25% HgCl <sub>2</sub> as inhibitor	"	"
C3275	100% Anodite 7/1 - ore/black	Starch - flour paste 0.25% HgCl <sub>2</sub> as inhibitor	"	"
C3276	100% Anodite 7/1 - ore/black	Olin Starch formulation #2 - 0.25% HgCl <sub>2</sub> as inhibitor	"	"
C3279	30% Anodite - 70% African ore 7/1 - ore/black	Starch - flour paste 0.25% HgCl <sub>2</sub> as inhibitor	"	"
C3280	30% Anodite - 70% African ore 7/1 - ore/black	Olin starch formulation #2 - 0.25% HgCl <sub>2</sub> as inhibitor	"	"

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FIGURE 8A

Leclanche Type "D" Cells Stored At 160° F (Capacity)

Lot No.	Test Results						
	Cell No.	BA 30 (days)		BA 8 (hours)		BA 408/U (hours)	
		Initial	2 wks. at 160°F	Initial	2 wks. at 160°F	Initial	2 wks. at 160°F
C2329	1	11.6	8.8	157.7	16.0	19.7	14.3
	2	10.0		168.0	25.5	19.3	
	3	10.8		166.4		19.5	
	Ave.	10.8	8.8	164.0	20.7	19.5	14.3
C2332	1	9.6	6.0	168.0	107.6	18.8	10.8
	2	10.0	5.6	160.0	108.0	18.9	11.7
	3	9.6	5.4	160.0	112.0	24.5	11.8
	Ave.	9.7	5.7	162.7	109.2	20.7	11.4
C2335	1	10.2	7.4	165.3	133.3	18.3	13.0
	2	10.2	9.0	158.0	133.3	19.0	12.0
	3	10.4	8.0	165.3	131.2	19.3	12.0
	Ave.	10.3	8.1	162.9	132.6	18.8	12.3
C2338	1	10.0	5.8	156.8	86.6	21.1	11.4
	2	10.2	6.4	158.0	100.9	20.0	9.8
	3	10.2	6.8	155.4	120.0	20.2	12.0
	Ave.	10.2	6.3	156.7	102.5	20.4	11.1
C 2341	1	11.8	8.0	184.0	112.0	18.7	9.4
	2	12.6	3.2	188.0	105.1	16.7	10.8
	3	11.8		196.0	68.8	18.2	9.8
	Ave.	12.1	5.6	189.0	95.3	17.8	10.0
C2344	1	11.2	6.6	178.7	112.0	18.5	10.4
	2	11.8	5.8	192.0	100.0	16.8	10.2
	3	11.4	8.0	176.0	108.8	17.4	10.6
	Ave.	11.5	6.8	182.2	106.9	17.6	10.4
C2347	1	11.8	1.6	180.0	64.0	17.7	10.0
	2	12.8	3.6	184.0	108.0	18.3	7.6
	3	11.8	1.0	168.0	92.0	19.7	4.0
	Ave.	12.1	2.1	177.0	88.0	18.5	7.2

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FIGURE 8A (cont.)

Lot No.	Test Results						
	Cell No.	BA 30 (days)		BA 8 (hours)		BA 408/U (hours)	
		Initial	2 wks. at 160°F	Initial	2 wks. at 160°F	Initial	2 wks. at 160°F
C2350	1	10.4	9.4	166.0	21.3	20.0	6.9
	2	10.4	9.6	156.0		19.0	4.0
	3	11.0	10.2	168.0		19.1	
	Ave.	10.6	9.7	163.0	21.3	19.3	5.4
C2353	1	11.2	4.6	216.0	136.0	22.4	11.7
	2	11.8	8.2	212.0	144.0	16.7	12.0
	3	11.8	4.6	214.0	144.0	18.4	10.7
	Ave.	11.6	5.8	214.0	141.3	19.2	11.4
C2798	1	14.2	2.2	244.0	142.0	25.3	12.8
	2	12.8	7.0	242.7	144.0	20.0	10.5
	3	14.2	8.0	245.3		22.7	
	Ave.	13.7	5.7	244.0	143.0	22.6	11.7
C2774	1	13.8	6.6	232.0	136.0	25.5	11.0
	2	16.8	6.6	221.3	160.0	24.7	11.5
	3	16.2	8.8	236.0	112.0	25.4	13.1
	Ave.	15.6	7.3	229.8	136.0	25.2	11.8
C2775	1	14.2	9.6	244.0	164.0	25.3	18.0
	2	12.8	11.4	242.7	145.2	20.0	18.9
	3	14.2	12.0	245.3	197.3	22.7	16.0
	Ave.	13.7	11.0	244.0	168.8	22.6	17.8
C2776	1	14.2	12.4	244.0	196.0	25.3	18.0
	2	12.8	11.2	242.7	197.3	20.0	16.0
	3	14.2	11.2	245.3	168.4	22.7	17.1
	Ave.	13.7	11.5	244.0	180.4	22.6	17.1
C3267	1	22.8	8.0	328.0	94.9	28.4	12.0
	2	18.6	6.2	328.0	128.0	40.0	15.7
	3	19.4	8.0	332.0	82.7	39.0	14.7
	Ave.	20.3	7.5	329.0	101.8	35.8	14.1

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FIGURE 8A (cont.)

Lot No.	Test Results						
	Cell No.	BA 30 (days)		BA 8 (hours)		BA 408/U (hours)	
		Initial	2 wks. at 160°F	Initial	2 wks. at 160°F	Initial	2 wks. at 160°F
C3268	1	21.6	8.6	328.0	117.5	34.8	24.0
	2	22.4	8.6	336.0	109.3	40.0	26.2
	3	22.6	9.2	256.0	96.0	39.5	25.5
	Ave.	22.2	8.8	306.0	107.6	38.1	25.2
C3271	1	17.2	2.0	256.0	97.0	29.6	14.3
	2	16.6	1.2	239.1	114.2	27.3	
	3	17.0	1.0	203.0	99.1	28.7	
	Ave.	16.9	1.4	238.3	103.4	27.5	14.3
C3272	1	12.2	6.0	197.1	136.0	26.9	10.7
	2	13.0	6.8	188.0	130.7	28.7	9.0
	3	8.8	7.8	216.0	136.0	30.8	
	Ave.	11.3	6.9	200.3	134.2	28.8	9.9
C3275	1	21.6	3.8	272.0	Cells	32.8	Cells
	2	17.2		296.0	no	33.2	no
	3	20.0		280.0	good	30.7	good
	Ave.	19.6	3.8	289.3	-----	32.2	-----
C3276	1	12.8	4.8	272.0	116.8	35.2	4.0
	2	12.8	6.0	196.0	16.0	32.8	7.7
	3	12.8	4.2	216.0	42.7	36.0	
	Ave.	12.8	5.0	228.0	58.5	34.7	5.8
C3279	1	15.6	9.2	232.0	117.7	25.6	15.2
	2	15.6	10.0	221.3	105.2	25.2	16.5
	3	14.6	9.6	236.0	145.1	26.4	
	Ave.	15.3	9.6	229.8	122.7	25.7	15.8
C3280	1	12.6	3.2	205.3	94.0	27.0	12.0
	2	12.8		202.7	136.0	27.4	12.0
	3	13.6		204.0	109.7	27.8	10.5
	Ave.	13.0	3.2	204.0	113.2	27.4	11.5

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RECOMMENDATIONS

1. The designed polarization apparatus be employed to evaluate new anodic inhibitors eliminating the complicated reactions occurring in the cathode area.
2. Manganese dioxides having a stable crystal structure and giving consistently high capacity results should be used in the fabrication of cells for storage condition specified in this contract. Gamma-B and cryptomelane crystal structures afford the best characteristics in achieving this purpose.
3. Paper lined cells using Eveready methyl cellulose coated paper, African ore depolarizer, polyethylene gasket and heat resistant polystyrene top seal, will meet the storage conditions of 130°F, 50% R.H. and 160°F, 50% R.H.
4. Polyethylene gasket substituted for the wax sub-seal and heat resistant polystyrene top seal will produce an effective seal that is resistant to cell leakage.
5. The application of (0.3%) ammonium chromate inhibitor (by weight of electrolyte in the separator) and 1% barium chromate (reservoir in the mix) for fabricated cells create performances which meet the conditions specified by this contract.

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